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HMI Solution between a manual operator and a pump drive
Based on Smart Phones

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HMI Solution Between a manual operator and a pump drive based on Smart Phones

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Abstract

With the development of modern technology, mobile communications are changing people's life and making their day to day life activities easier. The aim of this thesis work is to address one of the modern technology solution that simplifies and act as an HMI solution between a pump drive and a operator based on smart phones.

Xylem provides a wide range of pump control units, serving several advanced features includes condition monitoring, cleaning sequence, flow calculation, energy optimizer, sump cleaning and so on. Smart run is a pump control unit, whose parameters installed at wastewater pump stations are possible to monitor and configure physically using keypad or remotely using extension communication gateway, which is a costly solution for installations and maintenance. So, a simple working prototype HMI solution based on smart phones is interested to see how smart phone can relay information between a pump control and an operator in the vicinity of the pump.

For this approach a thorough study has been done on different types of smart phones, their trends and different possible wireless communication solutions between operator's smart phone and the pump. An interactive design process with a focus on usability and data representation on a smart phone application was developed to support their needs and provide a cost effective solution.

The result showed that this approach has many benefits includes serving as cost effective HMI solution, data monitoring, better alarm monitoring with additional information, enhanced display over Smart Run's OLED displays, multilingual support, provides easier support services and also useful as a receiver unit for dewatering pumps hardware developed in parallel with this thesis.

This thesis work is carried out in Xylem Water Solutions AB[1], Stockholm, Sweden in collaboration with Mittuniversitetet[2], Sundsvall, Department of Electronics Design. This report can be used as groundwork for future development of smart phone applications for Xylem products.

Keywords: Human-machine-interaction, Smart phone, Mobile Application, Wireless communication.

[1] *http://www.xyleminc.com*
[2] *http://www.miun.se*

Foreword

I consider it an honor to work in a global organization, Xylem. The working culture, sharing platform with experienced colleagues, knowledge developed and the support provided is surely a value added experience to my career.

My sincere acknowledgement will go to Jurgen Mökander, Manager, R&D Electrical components and systems, Xylem for giving me this wonderful opportunity to do my Master thesis. With grateful thanks, I express my deep sense of gratitude and respect towards my supervisor Dr. Benny Thörnberg, Mittuniversitetet, for his valuable suggestions, guidance and encouragement throughout the thesis work.

Obviously I am very much thankful to Alexander Fulleman, Development Engineer, Xylem and Martin Zetterquist, Development Engineer, Xylem for supervising my thesis work at Xylem. Their timely suggestions, feedback were really helpful and the chance given me to have regular discussions, meetings with them was really helpful and made me keep up to meet time lines of the thesis work. Also am thankful to Henrik Myringer, Martin Wessmann, Gunnar Törnqvist and the people from reference group for their presence in progress meetings and the interest shown during the thesis work.

I would like to take the opportunity to thank my friend, Jagan Mohan Krishnaraj, for accompanying me throughout the thesis work and the discussions during thesis were helpful in decision making. Also am very much thankful to my friends who being supportive and encouraging throughout my academics.

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Terminology

HMI	Human Machine Interface
LED	Light Emitting Diode
CS	Check Sum
CMD	Command
ADR	Address
OLED	One-line Light Emitting Diode
PDA	Personal Digital assistant
PC	Personal Computer
BLE	Bluetooth Low Energy
NFC	Near Filed Communication
SIG	Special Interest Group
ISM	Industrial, Scientific and Medical
GATT	Generic Attribute Profile
AP	Access Point
GPS	Global Positioning System
OS	Operating System
DVM	Dalvik Virtual Machine
APK	Android Application Package
SDK	Software Development Kit
IDE	Integrated Development Environment
ADT	Android Development Tools
MFI	Made For iPhone
BT	Bluetooth
API	Application Programming Interface
IDC	International Data Corporation

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1 Introduction

1.1 About Xylem

Xylem is a water technology company, providing equipment and services for water and wastewater applications with a broad portfolio of products and services that address the full cycle of water. Over 12,900 employees from 320 locations on 6 continents strive towards the solutions to answer the needs of the consumer base[1]. Xylem deploys several methods to ultimately provide the best water saving solutions.

1.2 About Water treatment Cycle

In the process of water treatment cycle, waste water coming from residential usages and drainage water is collected at pump stations set up in the several regions of county. The collected waste water from the sump is then pumped to central wastewater treatment plant where it is processed into hygienic purified water. In pump stations the collected waste water is pumped out through pipes using pumps. These pumps are controlled and operate with pump controllers for better pumping solution and work efficiently. For this purpose xylem uses several pump drives, among which smart run[2] is a multifunctional pump drive that monitors and controls the pumps and keep the water cycle process.

1.3 About Pump Stations

Below Figure 1.3.1 shows the practical scenario of the pump station showing the setup of sump, pumps, Smart Run, level switches, inlet and outlet pipes of the waste water.

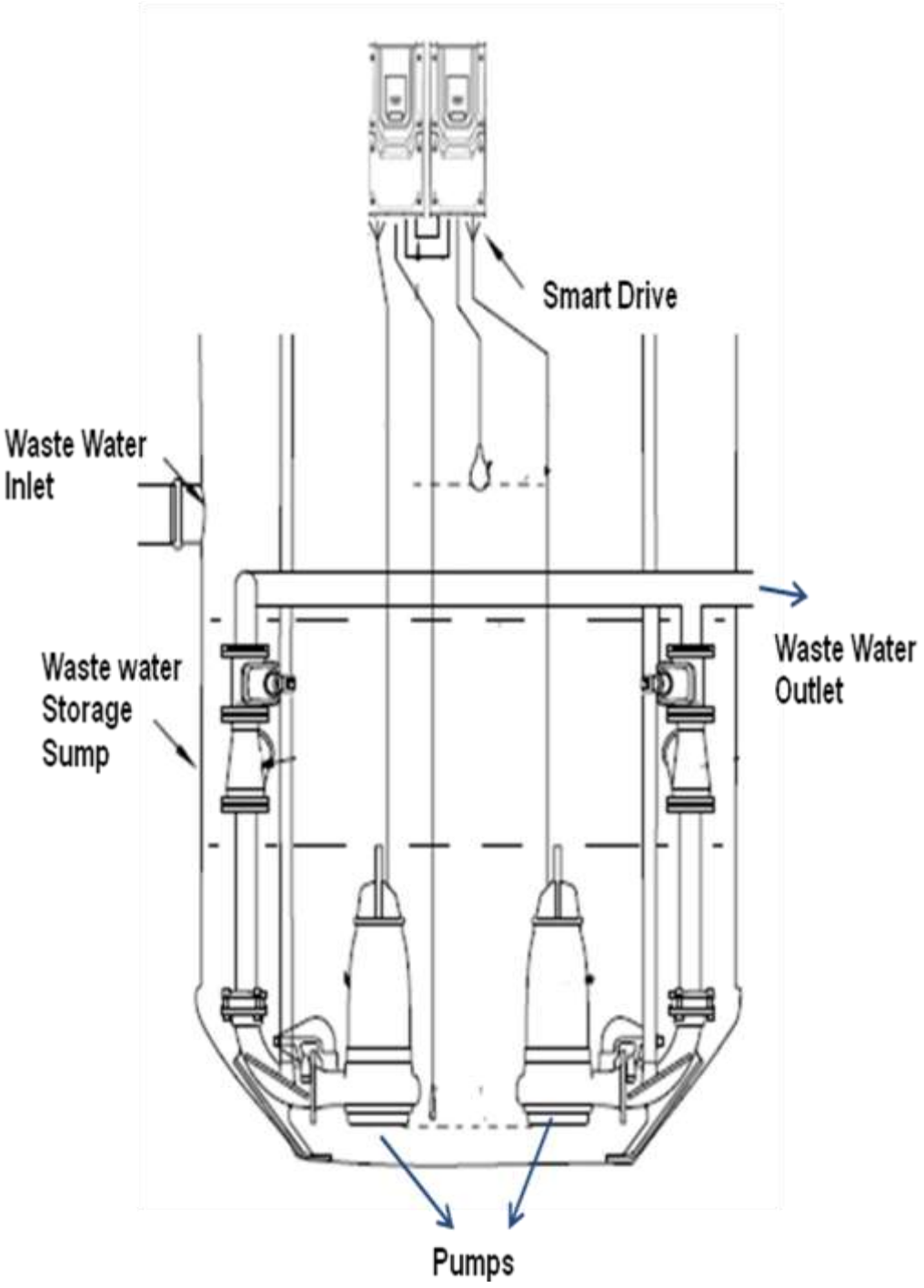

Figure 1.3.1 : Scenario at typical Pump Station

1.4 Background and problem motivation

Xylem comprises three business units Water Solutions, Analytics and Applied Water Systems. In today's state of the art applications at Xylem Water Solutions AB, Sewage application, drainage pumps and dewatering pumps use different solutions like LEDs and single-line displays that constitute a common interface between the operator and the pump.Xylem Water Solutions AB, provides several monitoring and control operations to their customers.

SRC 311 (Figure 1.4.1 : Smart Run Units) is a pump drive with Smart Run functionality, dedicated for waste water pump stations. Several configurations can be set to drive the pump as per requirements.

Today these drives have several limitations and can be summarized as, presently smart run parameters installed at wastewater pump stations are possible to monitor and configure physically using keypad or remotely using extension communication gateway (Fieldbus), which is a costly solution for installations. Smart Run can only save very limited data (kWh, running time, alarms, trips) and requires constant polling to receive trend data.

The drive parameters are read over OLED display allowing to show limited information, alarm notification with limited information and due to memory management issues today smart run is limited to nine languages. These drive provides only computer connected support service. Today laptop and Optistick/RS485 connection and optitools PC software is required for programming and in fault cases there is no simple solution for operator to give drive settings to the support services.

Figure 1.4.1 : Smart Run Units

In parallel with this thesis another master thesis for dewatering applications is carried out. The objective of this thesis is to develop a data logging system and wireless communication from inside the pump. For this a smart phone application is intended to serve as a reception and display system. Therefore to meet the above requirements this master thesis is proposed which would solve the drawbacks in wastewater treatment applications and act as reception unit for dewatering applications.

1.5 Overall aim

The overall aim of this thesis is to develop knowledge within the organization about different mobile operating systems, their trends, smart phone features and compare different communication solution between the operator and the pump, how today's smart phone could be used by operators and service personnel working with pumps in water solutions". The main idea of this thesis is to provide a simpler and cost effective communication platform based on today's modern smart phones for communicating with these systems. For this purpose, to show proof of concept and study different possibilities Smart Run pump drive has been selected to start with.

1.6 Scope and Limitations

Identify and illustrate information and configuration options between the operator's Smartphone and pump for sewage application and a drainage pump function. The focus is not on the pump information to be displayed to the operator or the information to be forwarded to the "cloud".

1.7 Concrete and verifiable goals

- Comparison of Mobile Wireless Communications
- Comparison of Mobile Operating Systems
- Development of a prototype smart phone application that serves as HMI between the operator and the pump station, which should be:
  - Simple
  - Cost Effective

1.8 Specifications of HMI solution

- Monitor and Controls the Smart Run at the pump station.
- Provides better support service for the operator in fault situations.
- Provide security for application in order to avoid misuse by unauthenticated persons.
- A mobile application that solves above stated limitations as in problem motivation section.

1.9 Application performance analysis

- Time for setting up Connection
- Time for loading groups with Individual parameter accessing
- Time for loading groups with multiple parameter accessing

1.10 Outline

Chapter 1 Introduction to the company, basic information on wastewater treatment cycle, background and problem motivation for this master thesis, overall aim, scope and limitations of the thesis and verifiable goals to be met at the end of the thesis work.

Chapter 2 Related work presents some discussion on related research papers and similar applications that are available in the market.

Chapter 3 Theory Introduction to smart run, its interface feature, Optibus protocol communication and the commands related to Optibus communication. Different wireless technologies, their features, advantages and disadvantages, comparisons of these technologies and market statistics on a future forecast of these wireless technologies. Also about different mobile operating systems and some forecast of these mobile operating systems.

Chapter 4 Methodology: Selection of wireless technology, selection of mobile operating systems, performance analysis and the tools used to develop the proposed approach.

Chapter 5 Design: Implementation of several functionalities provided by this proposed prototype application and a glance on the test platform developed for testing the application.

Chapter 6 Results shows the test results of the proposed application and some application performance analysis results.

Chapter 7 Conclusion: The application solutions that would answer the limitations described in problem motivation section, how this approach would useful and what change this thesis solution would bring.

Chapter 8 Future work: Future possibilities that can be done in these fields and how it will be useful in the development of this approach to Xylem.

1.11 Contributions

The investigations, design and development of prototype smart phone application to communicate with smart run was carried out by Santosh Golla. Also another application usage for dewatering pumps, communicating from inside pumps system was carried out by another thesis work in parallel and receiving section for this is carried out by Santosh Golla.

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2 Related work

Smart phones besides usage for calling and messaging, have several applications in various fields such as domestic, agricultural, entertainment and industrial automation systems.

According to a recent research paper, "*Control of Industrial Systems Using Android–Based Devices*", by *Andrei Drumea*, [3] published in Electronics Technology (ISSE) - 36th International Spring Seminar, May 2013, the development in mobile devices and its enhanced features made them useful in several domains. Smart phones are widely used in industrial controlling systems serving as easy and cost efficient human machine interactive solutions. With excellent input option (touch screens), several connectivity provisions both local (Bluetooth, USB, WI-Fi, NFC) and remote (GPRS, 3G/4G GSM) has made them provide the easy communicable environment. The main advantage in using the mobile device controlled system is its low cost, no more required to carry computers, low power consumption and several communication capabilities to suit different scenarios.

Another paper "*Remote Monitoring and Control of Industrial Process via Wireless Network and Android Platform*" [4] published in Control, Automation and Information Sciences (ICCAIS), 2012 International Conference by *Nguyen-Vu Truong* and *Duc-Lung Vu*, demonstrate the control of industrial system with android based smart phone for monitoring and controlling of CNC machines. This paper describes the similar advantages like cost, communication capabilities and enhanced display for monitoring making smart phones beneficial in industrial applications. *Daniel Görlich*, *Peter Stephan* and *Jan Quadflieg*, "*Demonstrating Remote Operation of Industrial Devices using Mobile Phones*"[5] published in the 4th international conference on mobile technology, applications, and systems and the 1st international symposium on Computer human interaction with mobile technology, present a prototype system that uses mobile devices to monitor, diagnose and control plant components via Bluetooth and serving as an efficient HMI system solution.

Also, another research paper "*Android App for Intelligent CBM*" [6] by *Nishchal K. Verma, Sumit Sarkar, Sonal Dixit, Rahul K. Sevakula* and *Al Salour*, published in Industrial Electronics (ISIE), 2013 IEEE International Symposium present a smart condition based monitoring system. This approach has shown a cost effective solution as generally, installation of the specific equipment for monitoring is expensive.

Besides research papers on smart phone usage in industrial applications, it is found that few of the competitors of Xylem in pump applications have also been using a similar type of application. Namely Grundfos "*Grundfos GO APP*" [7], and Lindsay Corporation's "*Field Net APP*" [8].

Grundfos GO App:

- Product Control : Status, Alarms, R/W settings
- Product Selection
- Product Information

Lindsay Corporation :

Field Net App :

- Monitors Irrigation Fields
- Monitor and control pumps

3 Theory

3.1 Products at a glance

Today xylem has several monitoring and control products, useful in on / off and monitoring (alarms, telemetry, measurements). Each of these systems provides comprehensive pump control, advanced supervision of pump conditions, flow calculation etc. Below are some of the examples of pump controllers designed for use with a variety of pumping applications.

a) FGC300(S)

b) FGC 200(S)

c) APP 721

d) FGC 300(L) e) FGC 200(M)

f) MAS 711-Pump Supervision.

g) PS 200

h) Smart Run

i) Hydrovar

3.2 Smart Run

The Smart Run, SRC 311 is a pump drive with smart functionalities dedicated for waste water pump stations. It includes an energy minimizer function which typically reduces energy consumption compared to conventional on/off Systems.

Figure 3.2.1 : Smart Run

Some other features of Smart Run include:

- Sump cleaning, Pump cleaning
- Alarms (Leakage, high temp, high level etc.)
- Energy measurement (power, energy (kWh), current, voltage)

- Smart Run supports a wide range of communication protocols, field buses such as Ethernet IP, Profibus etc., through extension modules and Modbus RTU and OptiBus are natively supported.

With smart run several parameters like start level, stop level, motor rated voltage and several other configurations can be set. Smart run logs the motor run time, alarm log, power calculation, estimated service time and some other functionalities are monitored to run pumps efficiently installed at the pump stations. It is equipped with an RJ45 connector, this interface has two provisions for operating in two communication protocols, Modbus Communication Protocol and Optibus Communication Protocol. Through which either a network connection via wired or a wireless communication using Optistick Bluetooth module can be established [9] .

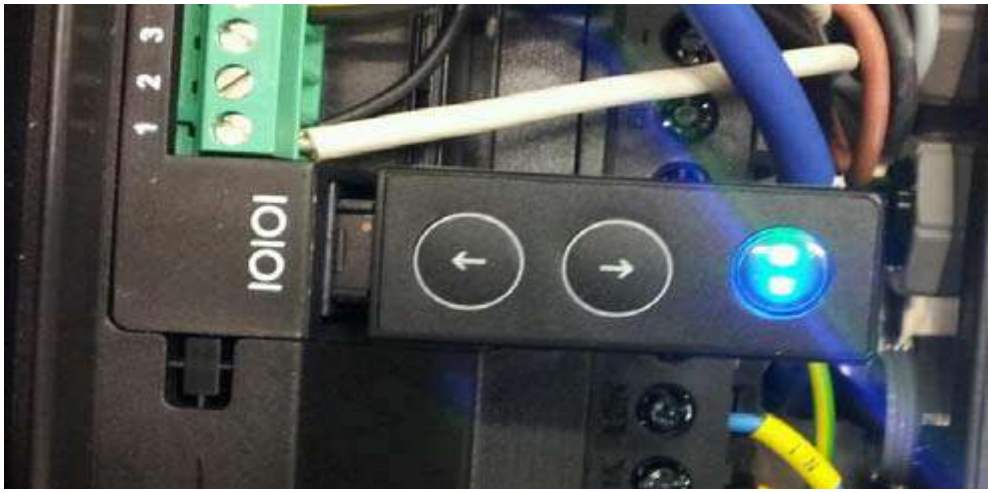


Figure 3.2.2 : Optistick Connection to Smart Run

3.3 Optistick Bluetooth Module

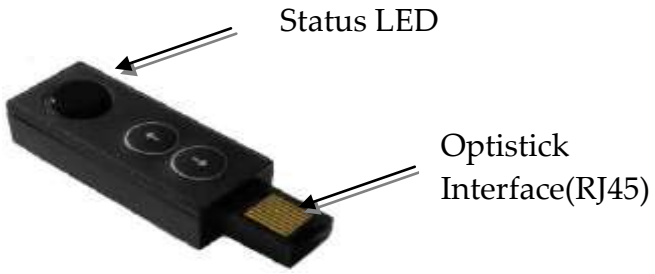
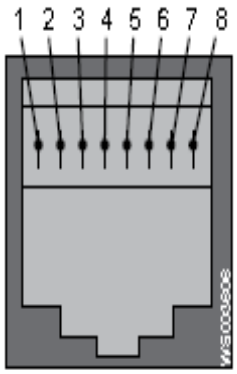


Figure 3.3.1 : Optistick Bluetooth Module

Optistick is a Bluetooth transceiver. It is built with Class II Bluetooth LMX9838 chip on it. Optistick interface is designed to interface with smart run's RJ 45 Connector. It uses a specially designed Optibus protocol for communication. The smart run RJ 45 connector pin configurations are:



1. Not used
2. Not used
3. 0 V
4. Optibus -
5. Optibus +
6. +24 V, power supply for the remote key pad
7. RS485- Modbus RTU/CanOpen
8. RS485+ Modbus RTU/CanOpen

Figure 3.3.2 : Smart Run RJ 45 Pin Configurations

3.4 Optibus Communication Protocol

In order to perform wireless communication with smart run, Optistick is used which uses the Optibus Communication Protocol. This protocol is specially designed for communicating with PCs or external keypads. It features several command sets to retrieve / set the parameters of Smart Run.

The communication baud rate is fixed at 115200bps with 1 start bit, 8 data bits and 1 start bit[10]. The client[3] has to send a request to access the parameters of the smart run. It takes about 60ms to get the reply message back. So, the client has to wait at least 150ms before resending any command. Optibus communication features several command sets to retrieve the parameters from smart run.

[3] Operator

3.4.1 Drive Status Request

Out: 8 Bytes

Start	Address	Command	Checksum	Stop

Return: 12 Bytes

Start	Address	Command	Drive Status	Trip Code	CS	Stop

Start/ Stop: Start and Stop flags for the whole command message
Address : Denotes Drive address
Command: Status Request Command
Checksum: ~(Address + Command)
Drive Status: Stopped/ Running / Standby mode
Using this command the drive status can be known to the client side whether the drive is running or stopped or several other modes of operations.

3.4.2 Drive Display Information

Out: 8 Bytes

Start	Address	Command	Checksum	Stop

Return: 30 Bytes

Start	Address	Command	Data	CS	Stop

Start/ Stop: Start and Stop flags for the whole command message

Address : Denotes Drive address

Command: Display Info Command

Checksum: ~(Address + Command)

Data : This command returns a 30 bytes of message of which 22 bytes are data part representing the motor speed, motor current, real time power, drive temperature and their units.

3.4.3 Read Parameter Value

Out: 14 Bytes

Start	Adr	Cmd	Ind 1	Ind 2	Ind 3	CS	Stop

Return: 30 Bytes

Start	Adr	Cmd	Ind 1	Ind 2	Ind 3	Data	CS	Stop

Command: Read Parameter Command

Checksum: ~(Address + Command + I1 +I2 + I3)

Ind 1 : Index 1 represents the type of parameter from several parameter groups

Ind 2 : Index 2 represents a subtype among the parameters

Ind 3 : Index 3 is always zero left for future use.

Data : This command returns a 30 bytes of message of which 16 bytes are data part represents parameter value, upper limit, lower limit, decimal place and display symbol.

3.4.4 Write Parameter Value

Out: 18 Bytes

Start	Adr	Cmd	Ind 1	Ind 2	Ind 3	Data	CS	Stop

Return: 18 Bytes

Start	Adr	Cmd	Ind 1	Ind 2	Ind 3	Data	CS	Stop

Command: Write Parameter Command

Checksum: ~(Address + Command + I1 +I2 + I3 + Data)

Ind 1 : Index 1 represents the type of parameter from several parameter groups

Ind 2 : Index 2 represents a subtype among the parameters

Ind 3 : Index 3 is always zero left for future use.

Data : This command writes a 30 bytes of message of which 4 bytes are data part represents parameter value.

There are several hundreds of parameters that contribute pump drive settings. All these parameters are read and written using the read and write commands set. Apart from these commands also special other command sets are available to read multiple parameters using few commands, to set multiple parameters, to restore to factory default and to check the drive mode is the drive in auto mode or in hand mode.

To maintain pumps at pump station in an efficient way the available parameters provided by the smart run defines the operation configurations. These configurations can be set and read via available Bluetooth module using Optistick through the RJ 45 connector connected to the smart run. It is important to have the minimum specified delay between the accessing the parameters from the client side in order to have a proper communication possibilities.

3.5 Communication Comparisons

A typical wireless communication has the capacity to interface with the physical & electrical world, sense and process this physical value in a wireless medium. With the introduction of low power wireless chipsets, the communication between sensors and client device has become easier. There are several wireless communication technologies available like Bluetooth, Bluetooth Low Energy, Near Field Communication NFC, Wi-Fi, Ant+ and Zigbee. Wireless communication is rapidly growing where there is a need in replacing wired communications. Based on the requirements of this trend, wireless communications provides several features like:

Mobility: Wireless Communications provides better mobility options in the fields of communication areas. These systems can be easily moved from one place to another.

Simplicity: Setup connection time is much faster compared to wired communications. In some situations it is very simple to change the whole communication system as per requirement without worrying about any setup barriers as could be experienced with wired communications.

Flexibility: Wireless communications can be easily established in certain situations where wired communication is practically impossible to build.

Cost –Saving : The cost of running wires and maintaining the links is higher than wireless communication in some situations as it uses air medium as a communication channel.

As wireless communication is a prerequisite in this thesis work and is aimed to communicate using smart phone, different wireless communications which comes with today's smart phones like Bluetooth, BLE, NFC and WI-Fi Direct technologies' features, advantages and disadvantages are compared. Below sections describe about each wireless technology.

3.6 Bluetooth Communication

3.6.1 Classic Bluetooth

It is a method for data communication that uses short-range radio links replacing cables. It was created by telecom vendor Ericsson in 1994[11], managed by Bluetooth Special Interest Group (SIG). The Bluetooth SIG is responsible in the development of specification, manages the qualification program, and maintain the standards[12]. For manufactures to develop a Bluetooth device it must be qualified to the standards defined by SIG. It operates in the range of 2400-2483.5 MHz, it is unlicensed Industrial, scientific and Medical (ISM) standards. Bluetooth use frequency hopping spread spectrum radio technique, it divides the transmitted data into packets and each packet is transmitted over one of the 79 channels having a bandwidth of 1 MHz[13] .

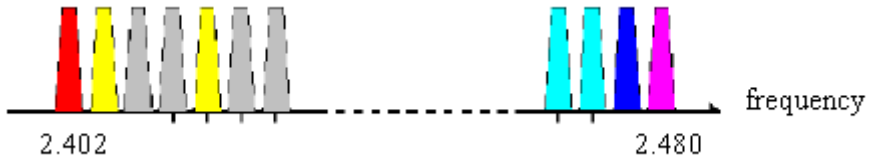


Figure 3.6.1 : Bluetooth Frequency Channel Divisions

There are three classes Class 1, Class 2 and Class 3, each class transmits with different power and has different range capabilities.

Class	Transmitted Power	Typical Range
Class 1	100mW	~ 100 meters
Class 2	2.5mW	~ 10 meters
Class 3	1mW	~ 1 meter

Table 3.6-1 : Bluetooth Classes Vs Power Vs Range

Different versions of Bluetooth are available and these versions differ in data rate.

Version	Data Rate
Version 1.2	1 Mbits/Sec
Version 2.0 +EDR	3 Mbits/Sec
Version 3.0 +HS	24 Mbits/Sec
Version 4.0	25 Mbits/Sec

Table 3.6-2 : Bluetooth Versions Vs Data Rates

3.6.2 Bluetooth Low Energy / Bluetooth 4.0

Bluetooth Low Energy previously knew as WiBree[14] is a subset of Bluetooth 4.0 with entirely new protocol stack from classic Bluetooth protocol stack for ultra low power consumptions. The aim of this technology is to provide long life without needing a new battery and run on coin cell batteries. This BLE 4.0 to be suitable for sports & fitness, health care, human interface (HIDs) and entertainment devices[15]. Bluetooth low energy is ideal for applications where the transfer of a small amount of data is intended with a periodic transfer rate.

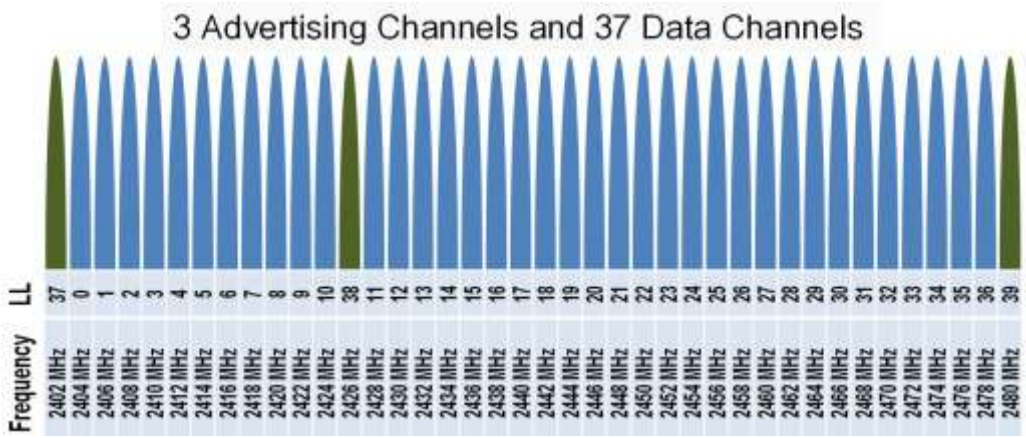


Figure 3.6.2 : BLE Frequency Channel Divisions

In a Bluetooth application where streaming data is used, Classic Bluetooth technology is the preferred choice as it achieves substantially greater throughput than Bluetooth low energy technology.

Low energy Consumption: BLE chips consume lower energy than classic Bluetooth due to its novel technique communication approach. In this approach it uses a lower duty cycle, which means the controller goes to sleep mode for longer periods of time and wakes up very less frequently to send and receive the data[16]. GATT profile makes the chip to be able to send smaller data packets in short bursts to save power. Also the controller doesn't maintain a link when the device is not in communication mode, this how the overall power consumption is less when compared to classic Bluetooth.

GATT: Generic Attribute Profile, this profile is responsible for sending a reduced amount of data being exchanged in order to maintain low power consumptions.

There are two modes of chips in BLE, Single -mode and Dual-mode chips. Classic implementations are single mode implementations, also there are single mode BLE devices.

Single Mode Devices : These are stand alone low energy devices also called as Bluetooth Smart, this device can communicate with only single mode devices i.e. BLE. These are not backward compatible. It is optimized for coin cell battery operated devices for low cost and low power implementations.

Dual Mode Devices: Unlike single mode these are backward compatible i.e. it can communicate with older versions of Bluetooth . It has both classic Bluetooth and Bluetooth low energy protocols which makes it backwards compatible. These devices are known as Bluetooth Smart Ready. Below diagram shows the compatibilities of Classic Bluetooth, Bluetooth Single Mode and Bluetooth Dual mode.

Figure 3.6.3 : Bluetooth Compatibilities

3.7 Near Field Communication

Near field communications, NFC is one of the latest wireless communication technologies used for very short range communications. Based on Radio Frequency Identification, NFC uses magnetic fields to enable communication between electronic devices. The maximum achievable communication range is limited to less than 10cm, where 4cm is the most use case communication range. It uses 13.56MHz for communication. The NFC forum[18], an organization that establishes and promotes the NFC standard, designed NFC to send data in three different transmission speeds. Currently, an NFC device can send data at a rate of 106, 212 or 424 kilobits per second. These speeds are fine for short bursts of information, but aren't suitable for heavy-duty tasks like streaming videos or playing games. Typically there are two pieces of technology involved in a near field communication process, an NFC-enabled device connecting/communicating with other NFC-enabled device or an NFC tag. These pieces can include both passive technology, where the item does not provide its own source of energy and as active includes a self-contained energy source. Significantly, passive NFC tags "can be made inexpensively and last virtually forever. Typically, an NFC tag is passive and stores data that can be read by an NFC-enabled device. Meanwhile, NFC-enabled devices, such as smart phones, are complex in their ability to switch operating modes[19] which can include:

- Reader/writer Mode: In this mode, an NFC-enabled device initiates an operation with a passive tag, such those on smart posters.

- Card Emulator Mode: Similar to a traditional contactless smart card, an NFC-enabled device will appear to a reader/writer as a passive tag, but in fact can be active, allowing it to look like any selectable number of tags for the users and also to allow the device to be read as a "default" tag when powered down or out of battery or without changing the existing infrastructure.

- Peer-to-Peer Mode: Here, two NFC-enabled devices exchange data , mandating both an active initiator and active target- i.e., a phone and another device (or another phone) sharing data as network peers.

3.7.1 NFC Applications

- Public transport
- Mobile payment
- Event ticketing
- Contactless payment cards
- Hotel keys
- Consumer services
- Smart Posters

3.8 Wi-Fi Direct Communication

Wi-Fi communications is a popular technology allowing electronic devices to share data or to connect internet using radio frequency. Wi-Fi Direct is a Wi-Fi Standard and is initially called as Wi-Fi P2P, that enables devices to connect easily with each other without requiring a wireless access point and to communicate at typical Wi-Fi speeds for everything from file transfer to Internet connectivity[20]. Wi-Fi Direct is designed to unleash a wide variety of applications which require device connections, but do not need the Internet or even a traditional network connection. Wi-Fi Direct supports communicates with typical Wi-Fi speeds, and can be as high as 250 Mbps. Wi-Fi Direct devices can communicate one to one or group of several devices can connect with each other simultaneously without cross talks. Wi-Fi Direct devices support connection with existing legacy Wi-Fi devices.

Wi-Fi Direct devices can connect anytime, anywhere connections. Since Wi-Fi direct doesn't need any Wi-Fi router or AP is not required, Wi-Fi devices can be connected everywhere.

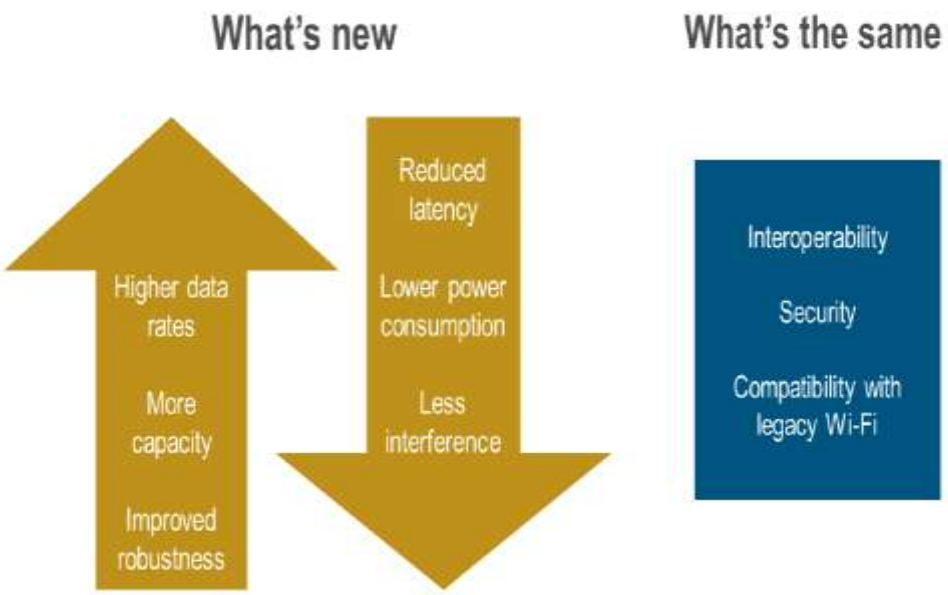


Figure 3.8.1 : Wi-Fi Direct Features.[21]

3.8.1 Wi-Fi Direct Applications

- Faster data requirements
- Share content
- Data communication
- Social networking
- Gaming
- Audio and video streaming
- Instant messaging
- Sharing pictures

3.9 Wireless Communications Market Statistics

According to a recent report from IMS Research, 'The World Market for Low-Power Wireless-enabled Consumer Electronics"[23].

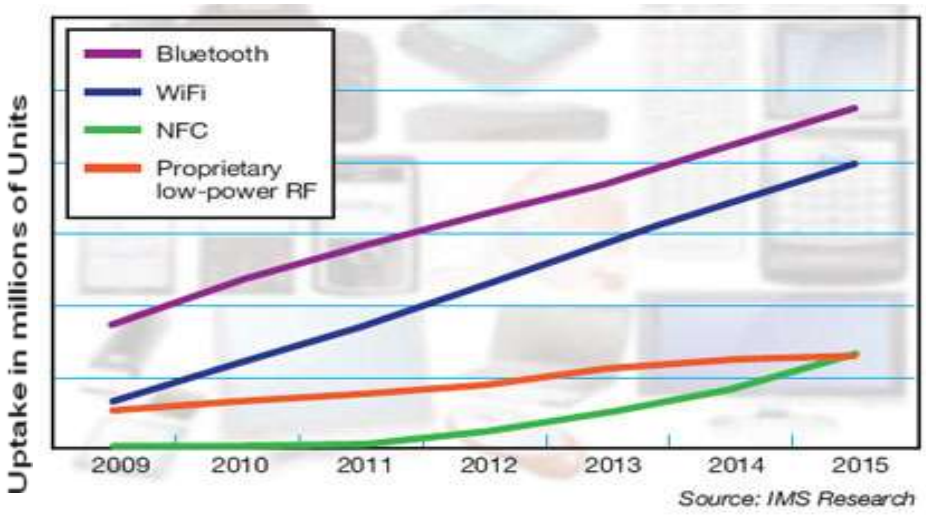


Figure 3.9.1 : RF Communications Market Statistics

From above research studies by IMS research, it can be observed that Bluetooth interface will be the most common feature in all consumer electronics (Smart Phones) for the next coming few years. Also, the below graph adds to the convention of these low power communication technologies [24].

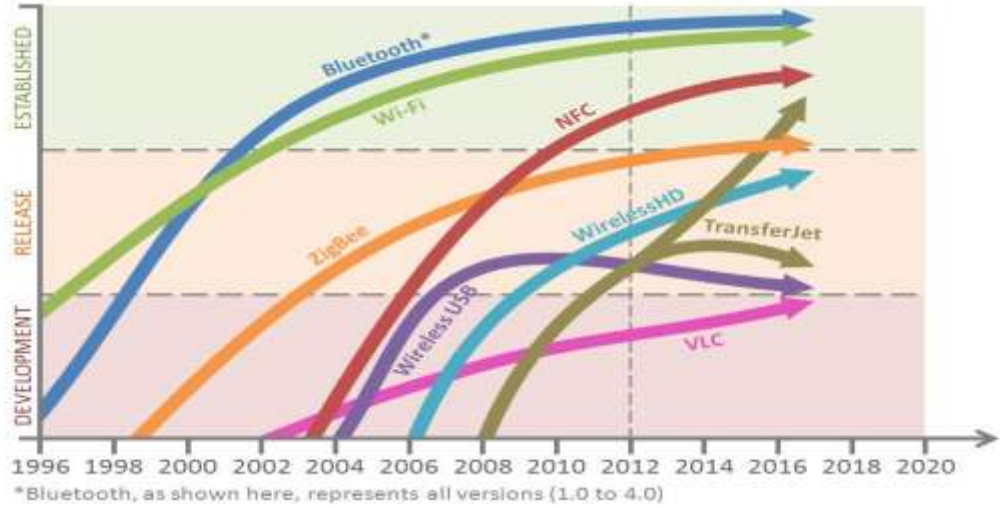


Figure 3.9.2 : RF Communication Technologies Forecast

3.10 Mobile OS Comparisons

As the thesis work is to develop an HMI based on Smartphone and is intended for use in commercial consumer products. So, It is interested to see as how today's mobile communications could be useful for Xylem products and some technical information about smart phones.

For this purpose a study has been made on smart phones, types of smart phones, different operating systems, their differences and trends in the market.

3.11 Smart Phones

Smart phone is a mobile phone built on a mobile operating system that has several advanced computational features and connectivity options compared with normal featured phone[25]. It has several features which makes it called as "Smart", these include portable media players, compact digital cameras, GPS for position services, high resolution touch screens, internet access, wireless communication options and so on.

Today's Smart phones are not only serving as a mobile device for communication rather they are used in many applications.

3.11.1 Applications of Smart Phones

- Mobile communications
- Industrial Applications
- Domestic applications
- Indoor housing automation system
- Control and monitor applications
- Public service applications
- Health Service applications
- Academic Knowledge base applications

Smart Phones have a wide usage in today's industrial applications, they are mostly used in control and monitoring scenarios based on different communication techniques as they support a wide range of communication possibilities. They provide users with a very good information in time and more securely. Also provides alerts, warnings and suggestions in emergency situations. Smart phones applications provide easier accessibility to the data with enhanced visualization on high resolution screens with easy to operate Graphical User Interface(GUI) to the operators.

3.12 Different Smart Phones Models

There are several companies that compete in today's mobile communications market like Google, Apple, Microsoft, Blackberry, Nokia and some other companies as well. The mobile operating systems used by modern smartphones include Google's Android, Apple's iOS, Nokia's Symbian, Microsoft's Windows OS, Blackberry Ltd's BlackBerry OS. Also there are few other upcoming operating systems in phones are Mozilla's Firefox OS, Canonical Ltd's Ubuntu Phone and Tizen.

The most popular smart phones that constitute today's market are Google's Android, Apple's iPhones up to 90% of market share as of July 18, 2013[26] the rest Microsoft's Windows phones and some proprietary Operating system phones. The major operating systems:

A) Google's Android Smart Phones

Figure 3.12.1 : Google's Android Logo

B) Apple's iPhones

Figure 3.12.2 : Apple's Logo

C) Microsoft's Windows Phones

Figure 3.12.3 : Windows logo

D) Nokia's Symbian

Figure 3.12.4 : Nokia's Symbian logo

Some other proprietary operating systems like Black Berry, Samsung's Bada. All these operating systems can be installed on many different phone models, and each device can receive multiple OS software updates over its lifetime.

3.13 Google's Android OS Smart Phones

Android is a software stack for mobile devices which includes an Operating system, middleware and key applications. It is an open source platform which made it grow rapidly and brought interest of many companies, developers and general public[27]. Since its release in October 2008 till present this platform has been constantly improving in terms of features and support for the latest hardware. This operating system can be installed on many smart phones, tablets and PDAs. On the other hand it's a Linux- Based architectural model allowing to fully use the features offered by Linux. Android applications are Java based, developers can create their own application according to the functionalities prerequisite. Android has many features which makes it special, but one important feature is Dalvik Virtual Machine (DVM), the major component optimized for low memory requirements and is designed to allow to run multiple instances at the same time. Android has a different selection of third party applications, can be installed by downloading from Google play store or by directly downloading and installing the application's APK file onto the device. All the applications are written in Java using the Android Software development kit(SDK). It includes a debugger, software libraries, APIs to build a typical android application.

There are several Integrated development environment IDE's provided by different companies, besides the official IDE is Eclipse using the Android Development Tools, ADT plug-in .

3.13.1 Architecture

The architecture of the Android operating system has several layers and can be subdivided into five layers : The kernel and low level tools, native libraries, the Android Runtime, the framework layer and on top of all the applications[28].

Figure 3.13.1 : Android's Architecture

Linux Kernel Layer

Linux kernel layer is the basic layer of android architecture. This layer interacts with the hardware and contains all the necessary hardware

drivers. These Drivers program controls and communicate with the hardware.

For example, consider the Bluetooth function. All devices have a Bluetooth hardware in it. Therefore the Linux kernel includes a Bluetooth driver to communicate with the Bluetooth hardware. Between the hardware and other software layers Linux acts as an abstraction layer.

Libraries Layer

The next layer is the Android's native libraries. This layer is responsible in enabling the device to handle different types of data. These are specific to a particular hardware and are written in c or c++ language.

Android Runtime Layer

This layer Consists of Dalvik Virtual Machine and Core Java Libraries

Dalvik Virtual Machine

It is a type of JVM used in android devices to run apps and is designed to perform low processing power and low memory environments. This DVM allows running two or more threads at the same time allowing multitasking applications.

Core Java Libraries

These libraries provide most functionalities defined in Java SE Libraries.

Application Framework Layer

These are the sections with which our applications interact with. As a developer, it is sufficient to consider these are some basic tools with which we can build applications.

Application layer

It is the top layer in Android architecture and this is where all the developer applications sit. Several standard applications come factory installed with every smart phone, such as:

- Home
- Dialer
- Contacts
- Browser etc.

As a developer it is possible to write an app which replaces any existing system app. That is, no limit in accessing any particular feature and can implement whatever is required by application to do with the android (as long as the users of your app permits it). Thus Android is opening doors for endless opportunities to the application developer.

3.13.2 Features

- Powers hundreds of millions of mobile devices in more than 190 countries around the world. Every day another million users power up[29].
- Connectivity Options
    - Bluetooth
    - Bluetooth Low Energy
    - Wi-Fi Direct
    - NFC
    - Web based
- Free App Development for developers
- Free SDK tool
- Open Source platform
- No Annual Charges
- Apps publication for 25 $ onetime fee.

There are several other features which make android so popular and grow rapidly in this competitive world.

3.13.3 Update Schedule

Google provides major updates to Android in every six to nine months with improved new features and advanced computational features to most compatible devices over the air. Applications can be developed with specific target based version levels or can also be developed for compatibility with all the operating system version levels. With a new version update the application already developed can be updated with minor changes to suit with latest software updates.

3.14 Apple iOS Smart Phones

iOS is developed and distributed by Apple Inc[31]. It is the second largest OS device that occupies in today's mobile market share globally. Unlike Android and Windows phone Apple does not license iOS for use of non-Apple hardware. iOS is based on the Darwin operating system. Developer applications are programmed in Objective C programming language. iOS can run on iPad, iPhone, and iPod devices, it provides the technologies required to implement native applications.

3.14.1 Architecture

The iOS architecture is layered and has four layers. It acts as an intermediate channel between the hardware and the applications developed. The layers are classified as a Cocoa Touch layer, Media layer, Core Services layer and Core OS layer[32].

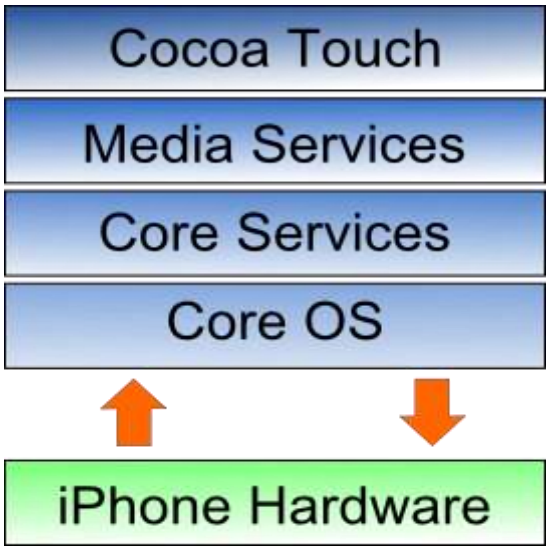


Figure 3.14.1 : iOS Architecture

3.14.2 Features

- Occupies 23 % of Market world wide
- Connectivity Options
  - Web based
  - Bluetooth*
- 99 $ App Development
- Apps publication 99 $ to maintain at the apple store.

- Software OS : Mac OS
- Multitasking

* Requires MFI Certification for communicating with third party devices.

3.14.3 MFI Certification

Made For iPhone Certification is a licensing program authorizes external manufacturers' hardware to connect with iOS devices[33]. Apple Inc, strictly follows this certification in order to maintain the developers to meet the requirements as per MFI program standards to ensure Apple's brand image. So, for Classic Bluetooth access from non-Apple products, not a part of MFI program it is not possible to communicate with iOS products.

In order to use third party products to communicate with apple products, Apple performs multiple tests on product design, product quality, product compatibility, robustness, security concerns and performance analysis then issues MFI license. Apple charges near about $20,000 - $80,000 total to get a simple accessory to a production-ready design, depending on the complexity of the electronics[34].

Apple will take commercially reasonable efforts to respond to Licensee's requests for approval within three weeks after Apple receives the manufacturer's request. Apple has the right to cease the license if it finds that the device doesn't meet the requirements of the MFI license after issuing and blocks until meet the specific rules by MFI Program.

Figure 3.14.2 : Made For iOS Logo

Apple devices until version iPhone 4 have classic Bluetooth chips embedded on it and thus need MFI certification for communication with third party Bluetooth devices. But this can be overcome with introduction of Bluetooth Low Energy chips in the market, according to message from Brian Tucker, Senior Software Engineering Manager iOS Bluetooth Technologies Apple and Bluetooth SIG Board of directors member Bluetooth Low Energy is not a part of MFI accessory program[35]. A

third party application can interact with a BT LE accessory via new core library's provided by Apple, called Core Bluetooth. These libraries can be used with the devices starting from iPhone 4S, which means it is possible to communicate with iOS devices using Bluetooth as communication channel via Bluetooth Low Energy chips and Core Bluetooth Libraries. Still it can only be communicated with BLE on the manufacturers' hardware and needs MFI certification to communicate with classic Bluetooth devices. The mobile devices with BLE includes iPhone4S, iPhone 5, iPhone 5C, and the latest iPhone 5S as of today.

3.15 Microsoft's Windows OS Smart Phones

Windows Phone OS was developed by the Microsoft[37], it is the third ranking mobile operating systems that circulates in today's mobile market globally[38]. It is the successor of windows mobile platform , Windows phone 7 is the first generation of Windows Operating system mobiles released on November 2010 and the latest second generation Windows phone 8 was released on October 2012 with major changes in architecture, new features with improved functionalities.

3.15.1 Architecture

Windows Phone OS uses a layered architecture and provides most of the device driver code[39].

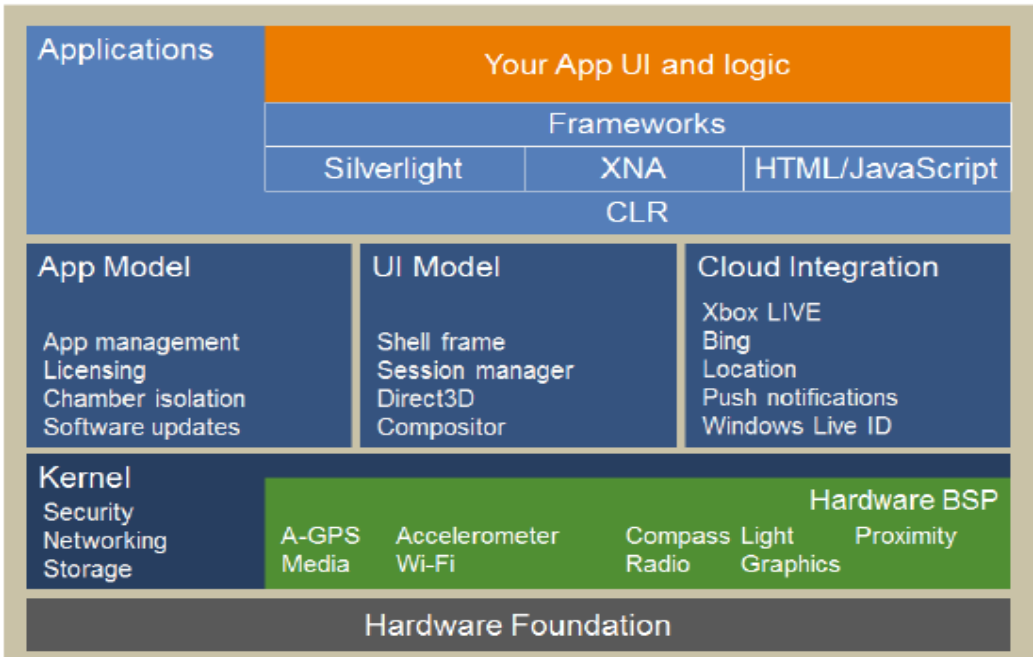


Figure 3.15.1 : Windows Phone OS Architecture

3.15.2 Features

- Connectivity Options
    - Web based
    - Bluetooth
    - Bluetooth Low Energy
    - Wi-Fi
    - NFC
- Free application development

3.16 Mobile OS Market Statistics

Mainly three mobile operating systems of smart phone's market strategies are analyzed as they share 90 percent of the mobile market. Namely Google's Android, Apple's iOS and Microsoft's Windows OS. All the statistical analysis results in this section discussed are part of major global market researchers includes International Data Corporation IDC, IMS Research, and Gartner Company.

IDC

International Data Corporation is an American market research, analysis and advisory firm specializing in information technology, telecommunications, and consumer technology[41].

IMS Research

IMS Research is a leading supplier of market research for the electronics industry[42].

E.g.: Communications, Automotive, consumer, power, medical and industrial firms.

Gartner

Gartner delivers technology research to global technology business leaders to make informed decisions on key initiatives.

It delivers the technology-related insight necessary for clients to make the right decisions on market strategies[43].

Following subsections shows the market strategies of mobile operating systems from the past, present and the future forecast as how the mar-

ket shares will last for the next few years. These statistic analysis gives an idea as which mobile operating systems are in most use and what operating systems is interested in development of the present proposed application has to be developed for.

3.16.1 Past Mobile OS Market Shares

The mobile market share is calculated in terms of the number of mobile devices sold for every quarter year.

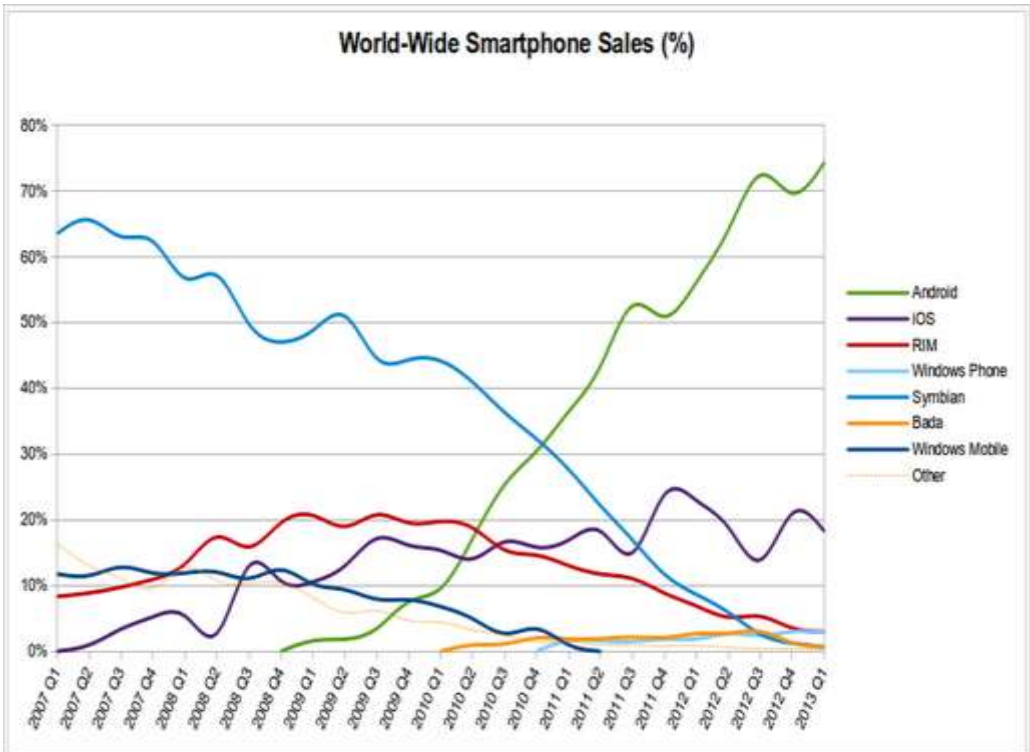


Figure 3.16.1 : Past Mobile OS Market Shares

According to Gartner Smart Phone Market Share[44], the above market analysis results for each quarter year starting from 2007 Q1 till 2013Q1 it can be observed that Google's Android share growth has quiet rapid development and share 70+ percent of the mobile market share. Apple's iOS has consistently maintained a share between 10% to 30%. Microsoft's Windows phone seems to have a decaying shares from its start of release into the market and shares only 3% – 5% during 2012Q3 to 203Q1, while operating systems like Symbian, Beta and others has completely put down and couldn't shown competing results compared with the giant operating systems.

3.16.2 Present Mobile OS Market Shares

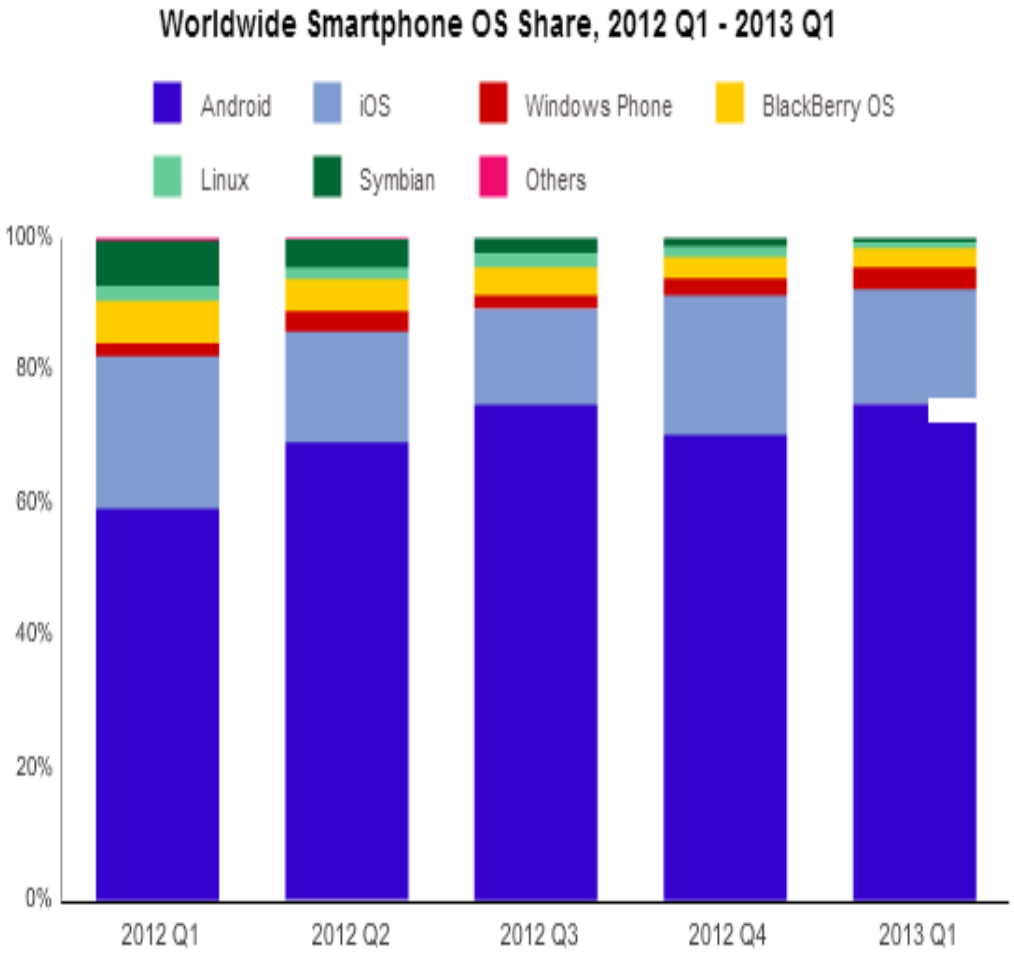


Figure 3.16.2 : Present Mobile OS Market Shares

According to IDC, International Data Corporation Android and iOS, the number one and number two ranked smartphone operating systems (OS) worldwide, combined for 92.3% of all smartphone shipments during the first quarter of 2013 (1Q13) and Windows Phone beats Black-Berry for 3rd place[45]. Android remains a leader in the Smartphone operating system market.

3.16.3 Future Forecast for Mobile OS Market Shares

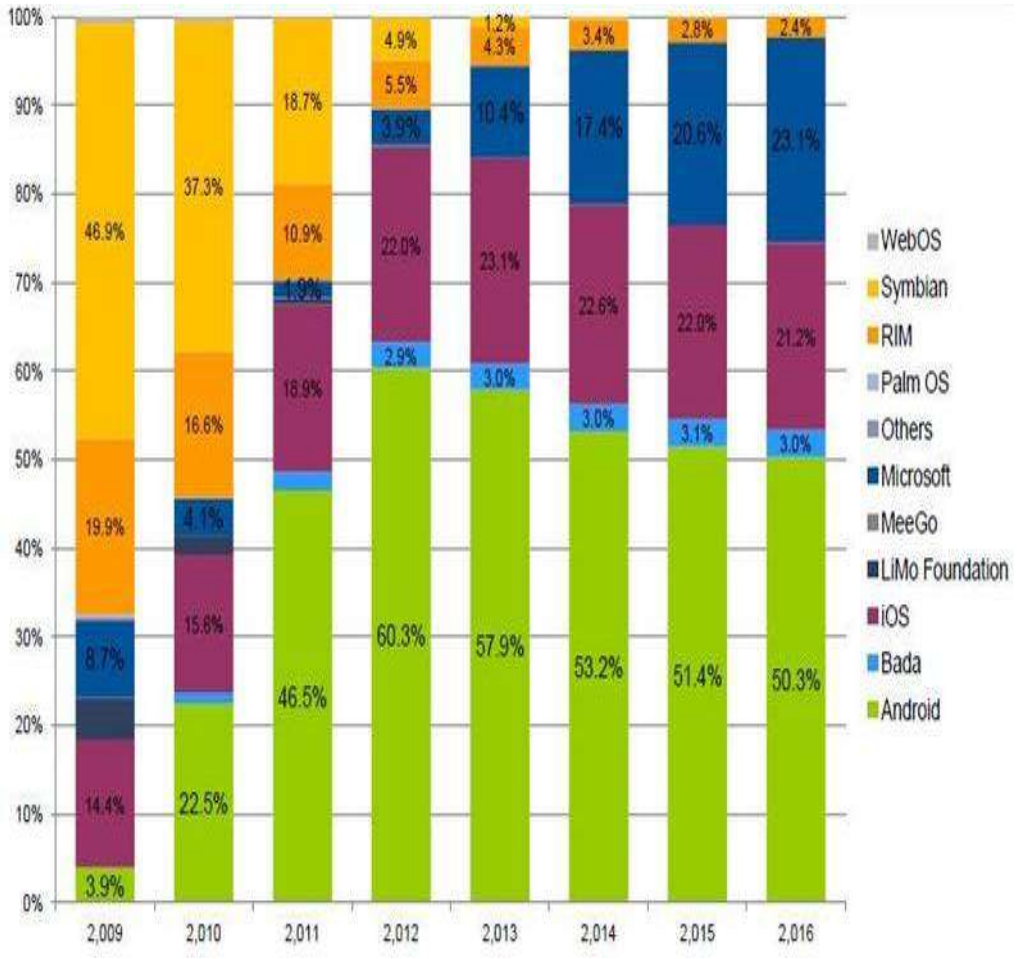


Figure 3.16.3 : Mobile OS Future Forecast

Source by Gartner forecast on future mobile operating system reveals that Google's Android operating system is dominating mobile operating systems shipments and will continue to lead the market through the next coming few years[46]. Windows OS will lead the market share of iOS and occupies second place in the global market. Windows OS after joining hands with Nokia, a global leader in mobile systems has led to this improvement in their sales according to the sources.

3.16.4 Mobile OS shares Regional Wise

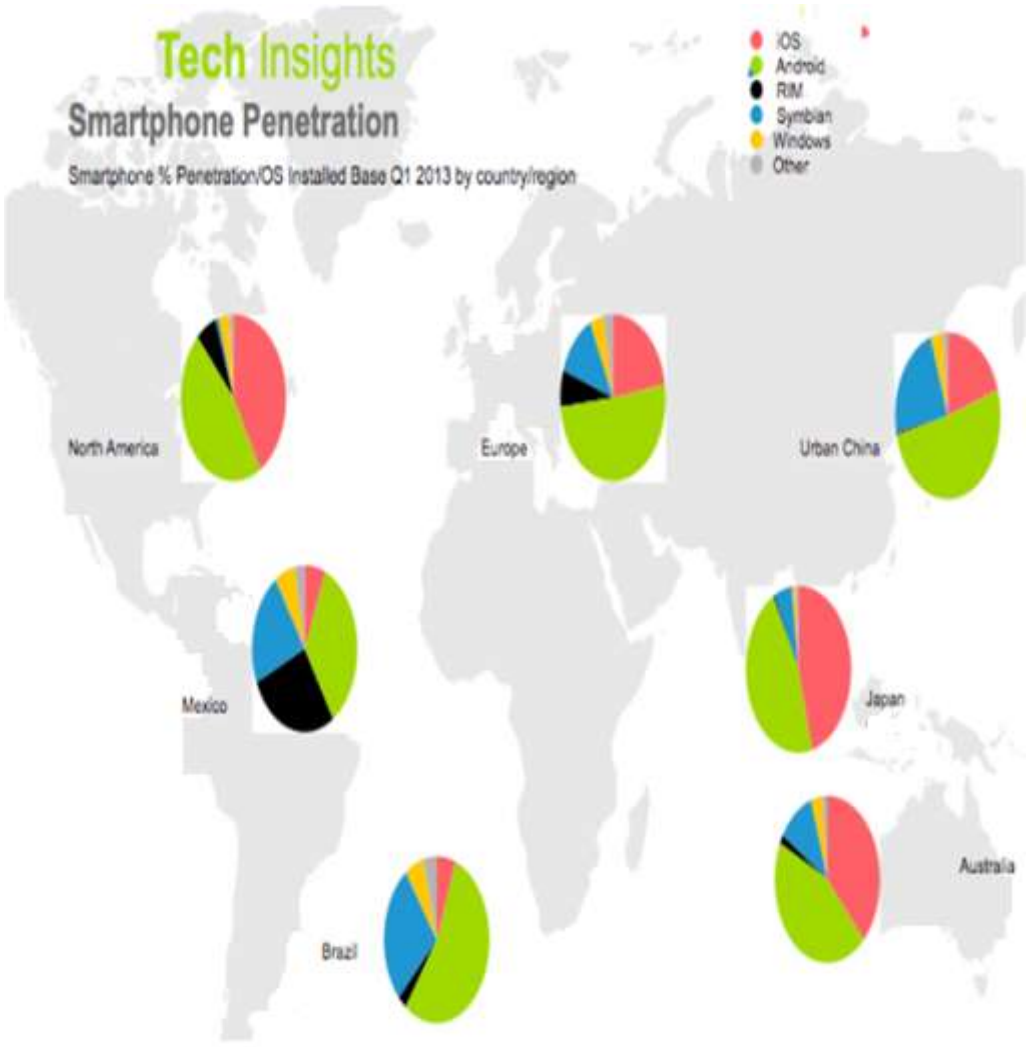


Figure 3.16.4 : Mobile OS Market Shares Regional Wise

Sources from Gartner and IDC statistics on mobile operating systems in regional wise[47]. It shows that all over the world smart phones has a huge interest over featured phones . It had brought a new revolution in mobile communications. Mobile phones no more just used as a device for voice call and SMS rather they are in many fields helping human day to day life much easier with presenting more and more information.

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4 Methodology

4.1 Proposed Solution

A working HMI solution using wireless communication between the operator and pump drive based on a Smart phone is the main interest in this master thesis. The block diagram below shows the overall solution that would solve many issues as described in section 1.4.

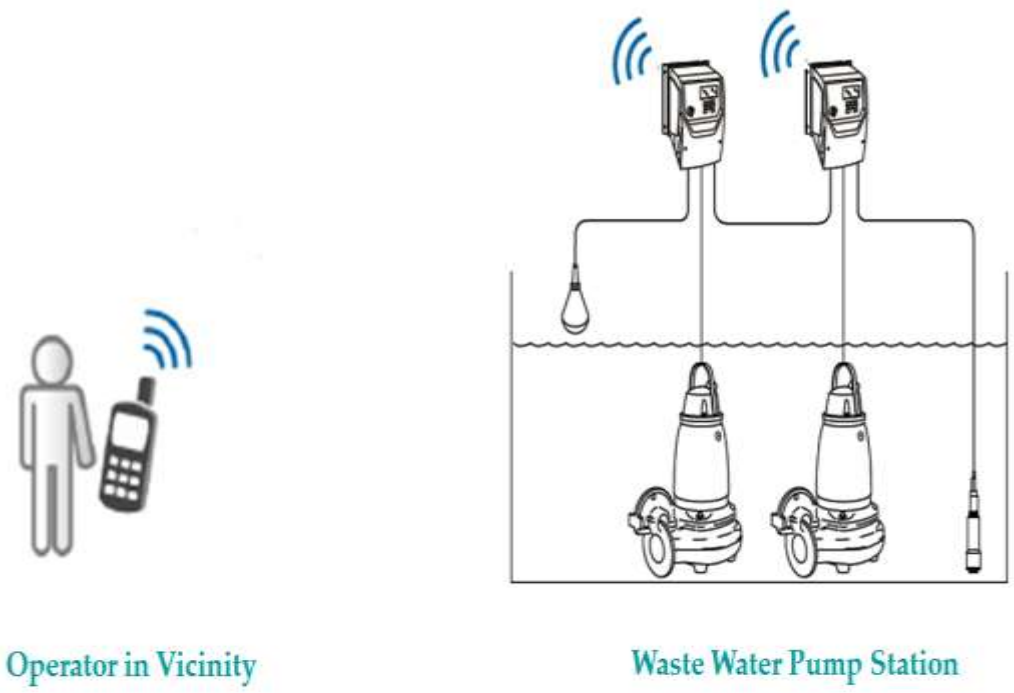


Figure 4.1.1 : HMI between Operator and Pump drive based on Smart Phones

The above approach as shown in Figure 4.1.1 , shall bring many usages to the operators and help them work in a more efficient way. To establish these system two main areas of interest can be considered, one wireless communication and two mobile systems. Here comes the question as which communication technology has to be chosen and what mobile operating system should be used to develop the proposed HMI. The following sections describe the reasons for selection of each platform.

4.2 Selection of Wireless Communication

Emerging new technologies in the field of wireless communication has lead to develop many applications which make human life easier. There are several low power short range wireless communications. Today's smart phone includes a variety of wireless communication technologies includes Bluetooth, WI-Fi Direct, Near Field Communications in most mobile devices. In this master thesis chapter 3 gives basic introduction, features of different wireless communications provided by smart phones. From chapter 3 it can be seen that Bluetooth is the most commonly used hardware and most mobile devices will includes this technology as a common feature of any smart phones. So, as discussed in chapter 3 the most powerful and famous technology, Bluetooth is chosen as the wireless communication platform and there are several other aspects which adds to the selection of wireless communication are discussed in the next subsection.

4.2.1 Reasons in Selecting Bluetooth Technology

Most importantly as Smart Run has Bluetooth Interface, in this thesis work the only possible approach at present to communicate wirelessly with Smart Run is via Bluetooth technology. Optistick as described in chapter 3 which is a wireless interface solution for Smart Run, comes with Bluetooth 2.0 Class II chipset.

Also, If the application is free to choose from several short range communications, Bluetooth seems to be the promising short range solution for this application due to below mentioned few other factors adding strength to the selection of wireless technology.

- **Faster Compared to NFC**: NFC transfer speeds are as low as just 424 Kbps where as Bluetooth can achieve a maximum transfer speeds up to 1Mbps. Even with NFC speed it is possible to establish a communication but consumes more than twice the time as compared with Bluetooth.

- **Wide range than NFC**: NFC has very less range which is a major drawback, it can communicate to max of < 5cms. Whereas Bluetooth can communicate till 1m or 10m or 100m depending the use

of Bluetooth class. Even Bluetooth doesn't solve remote service but will be advantage of having over NFC as in some situations smart run can be placed in some closed cabins during which NFC cannot reach operator's smart phone.

- **Backward Compatible**: There are different versions of Bluetooth and all the versions are compatible to each other. Except for single mode a BLE chip which is intended to communicate with only single mode BLE chips all the versions are compatible. When a dual mode BLE chip wants to communicate with its prior classic Bluetooth the dual mode capability can switch to operate in classic Bluetooth enabling compatibility to work in all modes.

- **Most Common features of all Smart Phones**: As can be seen from chapter 3 section 3.9, Bluetooth will be the most common feature of any smart phone. Starting from the most cheap mobile device to the latest costliest mobile devices has this feature.

- **Long Lasting Trend**: As the Bluetooth SIG has constantly kept researching and development, improving and maintaining the Bluetooth standards this makes the Bluetooth keep up on the market.

- **Low power communication**: As the proposed application usage is to communicate with smart run, which has several hundreds of parameters to me monitored the power usage by the wireless communication would drain out the battery soon. So, it is important to have a wireless communication which uses moderate power and for this reason Bluetooth which consumes less power when compared to WI-FI Direct is chosen.

- Open Communication system unlike Wi-Fi Direct.

- Best Short Range Communication with Smart Phones.

Based on all the above aspects Bluetooth communications is the best suitable technology that was chosen for developing the HMI based on smart phone.

4.3 Selection of Mobile Operating System

From the chapter 3 it can be seen that Google's Android OS and Apple's iOS OS are the two major mobile operating systems that constitute to 92.3% of mobile systems in today's market. The choice in selection of OS was open and as this smart phone application is intended for Xylem company usage, who has their products running all over the world Google's Android OS was the choice over iOS for this smart application due to below descried reasons.

4.3.1 Reasons in Selecting Google's Android OS

No Certifications: Using iOS devices in order to communicate with non apple devices it is mandatory to get MFI certification to use Bluetooth technology, for which it charges in thousands of dollars. In chapter 4 section 3.14.3, explains in more detail about MFI certification. But Android OS doesn't need any such certifications, it is an open source platform which opens doors for developers to create innovative applications.

Open source operating system: Android is open source and free, giving everyone the opportunity to create and spread own applications for the Android OS. Which gave a wide options in using the core libraries of this OS and was useful in implementing several features.

Leading Platform: From the chapter 4 market analysis it can be seen that past, present and future of the Android OS is the leader of all the mobile operating systems occupying the major shares and maintaining its brand image.

Long lasting: The future forecast according to IDC and Gartner for the next few years as can be seen in section 3.16.3, this Mobile OS shall be the leading and lasting mobile operating system.

Better Battery Capacity: when compared with Apple's iOS devices battery capacity it is seen that the Android OS devices ships with a higher battery capacity among smart phones.

Several Connectivity Options: Android for its developers provide several connectivity API's and options to develop any application according to the App requirements. It's free to use and easy to deploy any wireless communication includes Bluetooth, Near field communication, Wi-Fi Communication, Wi-Fi Direct communication or using network services.

Also, below mentioned few other factors which are not considerably important for xylem but are some other advantages over Apple iOS that can be noted.

Free IDE tool: Unlike Apple, Android has a free integrated development environment, IDE for its developers. All the required prerequisites can be easily downloaded.

Free App Developing: Google does not charge a single penny from the developers for developing the Android applications.

Ease of Access: Google provides several application examples, sources, and maintains developer portal and runs forums to support their application developers.

Zero Annual Charges: Google just charges one time charge for a very small amount of 25 dollars to place the application in the Google play store[48], application market for downloading the android application. Hereafter there will be no any annual charges to maintain at the store.

No Registrations: Developer can quick start developing the applications without requiring any registration unlike Apple application development which requires an account registration for its developers.

The above reasons made to choose Google's Android OS over iOS, also as Smart run is equipped with classic Bluetooth interface even after Apple iOS using BLE doesn't need MFI certification, and it is not possible to use as again to communicate BLE with classic Bluetooth for which it requires MFI Certification.

4.4 Performance analysis calculations

The Android's Bluetooth SPP doesn't have the specific data size boundaries. So, the received data come in separate packets. To make a meaning full message format a minimum time has to be maintained. For this purpose, Android's logging system LogCat is used to see the message. Below is the example showing the message splitting.

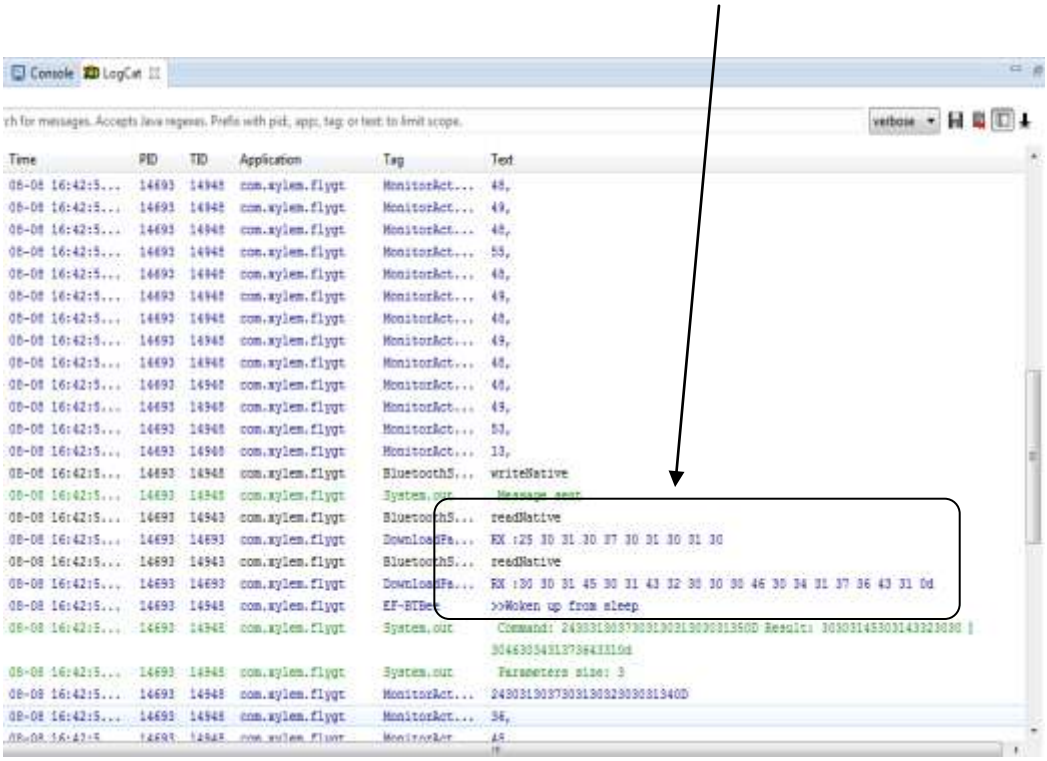


Figure 4.4.1 : HMI between Operator and Pump drive based on Smart Phones

From the above shown figure the box showing two separate messages with different length are a single message response but due to lack of data size boundaries the received message is obtained in two different instances with a slight delay. So, it is necessary to maintain a minimum delay during downloading data between each parameters to extract one complete message packet. The minimum time is measured by practical addition of short intervals of time programmatically in application during parameters downloading.

5 Implementation

In this design phase the theory, technical investigations, communication investigation and methodology proposed described in previous chapters was used.

5.1 Android Programming

Android applications are developed using the Java Programming language. The prerequisite tools required for developing application can be downloaded from the Android's web page.

5.1.1 Android application development prerequisite

1. Android SDK.
2. ADT plug-in for Eclipse IDE.
3. Latest SDK tools and platforms using the SDK Manager.

5.1.2 System requirements

- Windows XP (32-bit), Vista (32- or 64-bit), Windows 7 (32- or 64-bit) or Window 8.
- Mac OS X 10.5.8 or later (x86 only)
- Linux OS (Ubuntu Linux, Lucid Lynx)

Each user interface screen in the application is called as activity, and an application is made of one or several activities. Each activity is represented by a class, XML is used for designing the user interface. A mechanism called Intent is used for sharing data between the activities of an application. This application was developed and tested on Samsung Galaxy SII Android 4.1.2 Operating system (Jelly Bean) and also tested on the Samsung Galaxy Tablet.

5.2 Application Design Functionalities

The proposed smart application includes several features as below mentioned:

- Iconography and Login Screen
- Authenticated login
- Change language settings
- About the application activity
- Connection choices with SRC or with dewatering pumps application.
- Communicate using Bluetooth technology
- Display panel resembling SRC's panel
- Provide Buttons same as SRC's buttons
    - Menu Button
    - Start Button
    - Stop Button
- Alarm Monitoring
- Display Groups of SRC's parameters
- List view of Group's SRC parameters
- Edit parameter's value
    - Increment a value
    - Decrement a value
    - Data type dependency
    - Boundaries for the values
- Applying the change in Value to drive over Bluetooth
- Support Service
    - Email Smart Run Parameters
    - Email picture for fault connection verifications

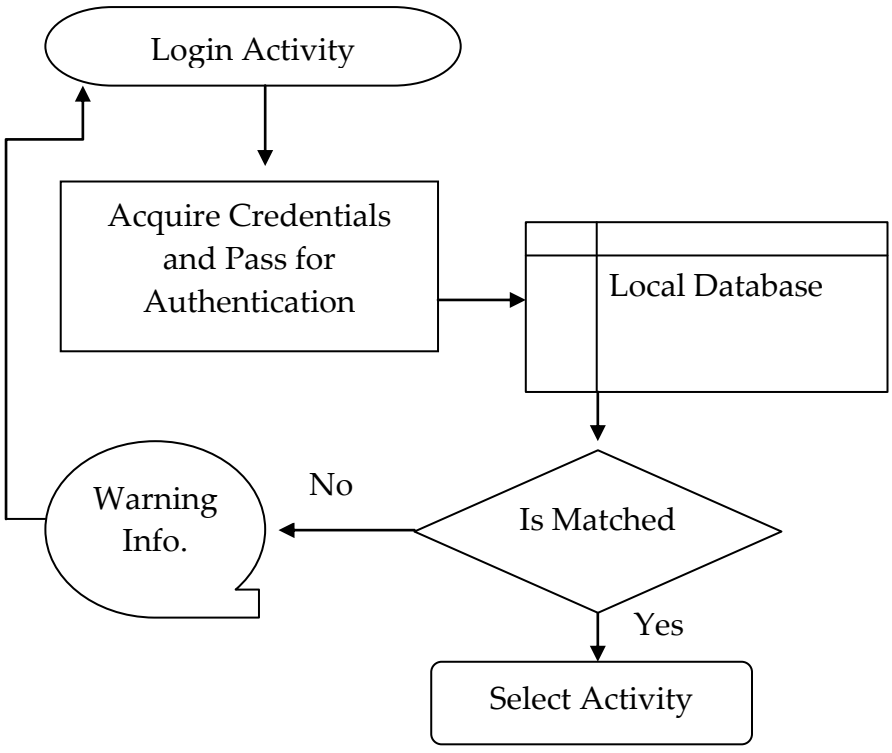
Detailed implementation description of the above actions are discussed in the following sections.

5.2.1 Iconography and Login Screen

Launch icon is the visual representation of the application on the screen which is used to start the application. A special care on the dimensions of the icon to be taken to support multiple sizes and different densities. Upon start of the application Login screen with user input fields is displayed. The user must input these fields provided by administrator to go further.

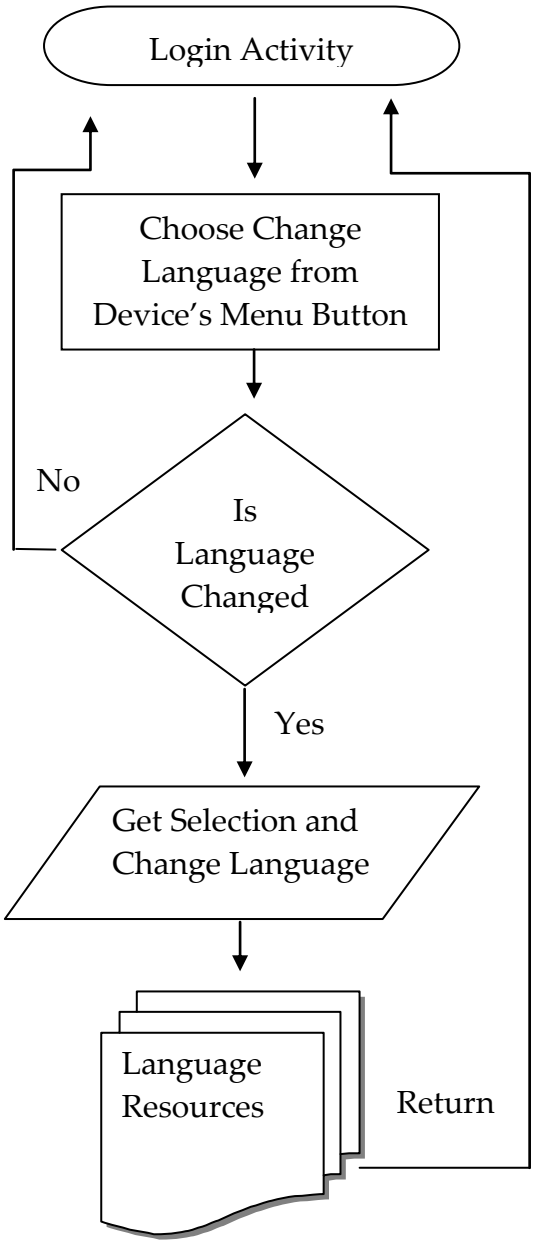
5.2.2 Authentication

For this implementation Android's session manager technique is used. Here the login credential is stored in local date base, shared preferences and when the user tries to login with appropriate credentials the details are reported for authentication and on successful authentication the user gets access to the application. Below represents the flow chart view of the authentication implementation.



5.2.3 Change language

In this master thesis to show language changes as a prototype working model two language options are provided includes English or Swedish. Also similarly limitless multilingual changing options can be added. Most of the content of application like display text, labels and descriptions are stored in resource files. Android uses the default resource files to load the application. These resource usage can be changes according to the user preferences. Upon device Menu press and change language selection a new activity is opened with a drop down list view of selectable languages.

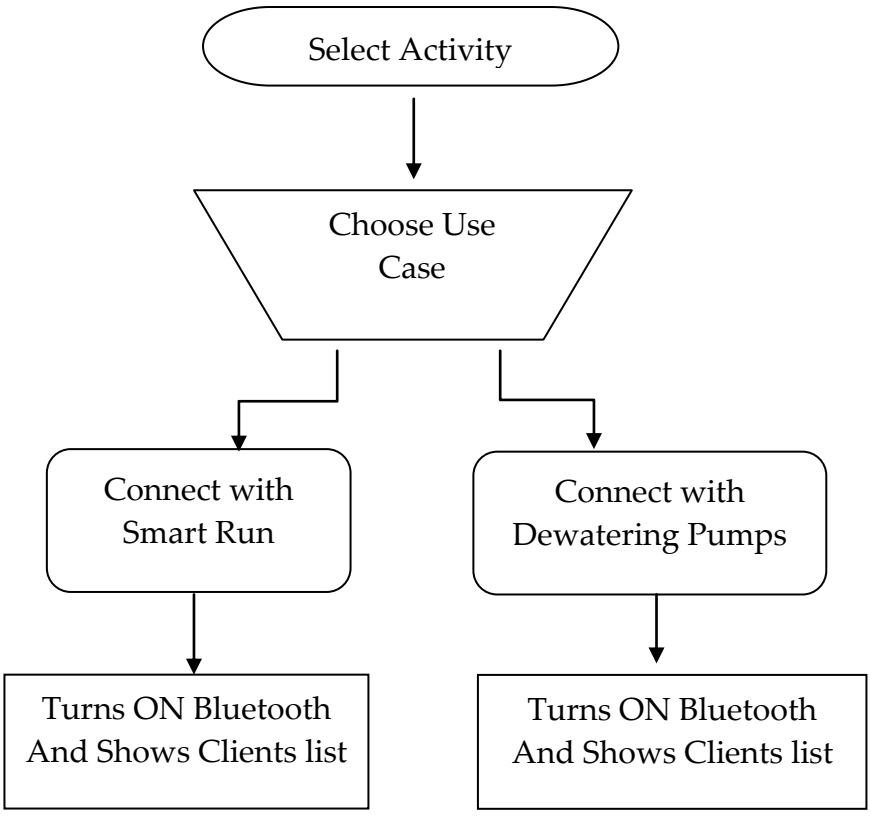


5.2.4 About Application Activity

This activity shows the basic information about the application, use cases, and some notes. This activity is implemented under the device menu button.

5.2.5 Select Connection Activity

In this activity two options with Image view buttons are displayed enabling two use cases. This smart application is intended for two main use cases firstly communicating with smart run and second communicating with dewatering pumps hardware which was developed by another parallel thesis work which is aimed to communicate from inside the pump. Each image button has a pictorial representation of the use case, so the operator can easily differentiate and select the right use case depending on the use of interest.

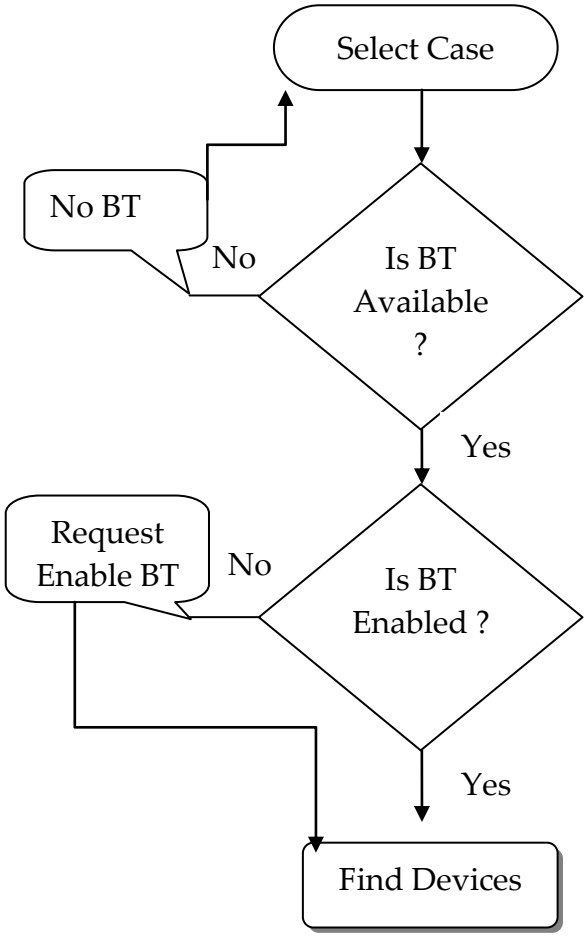

Select Activity
Choose Use Case
Connect with Smart Run
Connect with Dewatering Pumps
Turns ON Bluetooth And Shows Clients list
Turns ON Bluetooth And Shows Clients list

Selecting one of the use cases, Mobile's Bluetooth is enabled then searches for available Bluetooth devices and displays a list of Bluetooth devices within the vicinity.

5.2.6 Communicating using Bluetooth technology

Communicating using Bluetooth includes four main steps includes setting up Bluetooth, finding devices available in the local area, connecting devices and transferring data between the devices. In order to use mobile's Bluetooth by the application initially during installation application should confirm the permission to use Bluetooth.

Setting up Bluetooth: Before the start of Bluetooth communication this application checks for availability of Bluetooth and ensure that it is enabled. If Bluetooth is not enabled the app pop's up to enable the Bluetooth use permission.



Finding Devices : Also referred as Device Discovery or Inquiry or Scanning. In this phase the host mobile device searches for available Bluetooth device's information like device name, class and MAC address are read. A device list showing the device's information is presented, the device discovery process usually involves an inquiry of about 12 seconds.

Connecting to device: After retrieving the device's information the server's MAC address is used to initiate a connection. Here server is SRC or drainage pump hardware and client is refers Mobile application. They share a same RFCOMM channel after they establish a connection.

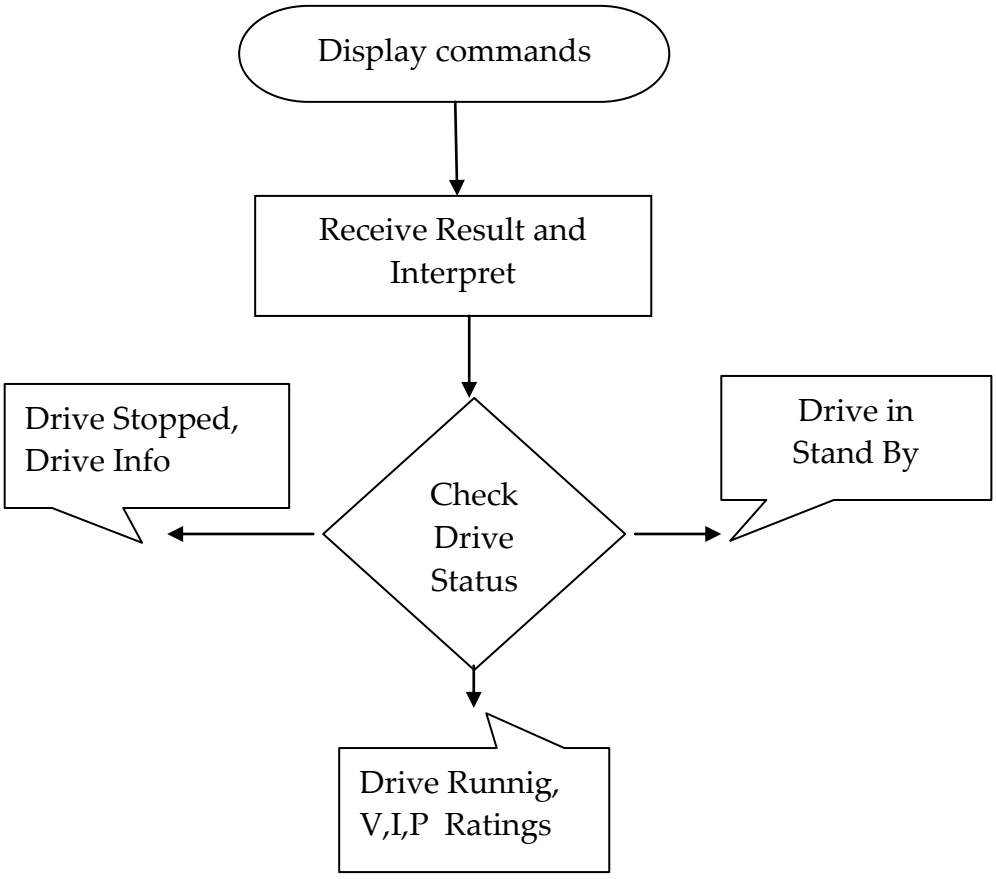
Transfer of Data: After successful connection both server and client will have a connected Bluetooth Socket. This socket is used to perform a transfer or receiving of data.

While communicating with SRC all the TX commands are defined according to Optibus Protocol standards to suit with the SRC understandable protocol. After executing a command from the client (Smart phone) the client (SRC) performs the action according to the command received and acknowledges back with a message containing the information of the action performed. The received reply from the SRC resembles in Optibus protocol format, this data is interpreted, changed into user understandable language and displayed over the user interface (screen). There are several commands as discussed in chapter 3 which perform respective actions upon request. A minimum delay of 200ms is maintained between each commands transfer as the SRC requires a minimal time to retrieve the data from memory and transmit back. Each SRC parameter has different type of units and notations, all these parameters are interpreted in respective format based on an index of the parameter as a reference.

The Android's Bluetooth SPP doesn't have the specific data size boundaries. So, the received data come in separate packets. To make a meaning full message format a smart mechanism is approached. In this mechanism the received data is saved in local table concatenating all the command's result as a single message and then an algorithm is applied that looks for the delimiter to separate the message.

5.2.7 Display Panel

This screen is designed to resemble with SRC panel for presenting the same experience as Smart Run's panel. This activity's interface screen is designed with three columns includes first column for title, second column for the value and notation and the third for displaying the ratings of the smart run. Below these columns user buttons are provided to perform the same actions as the actions in the smart run.



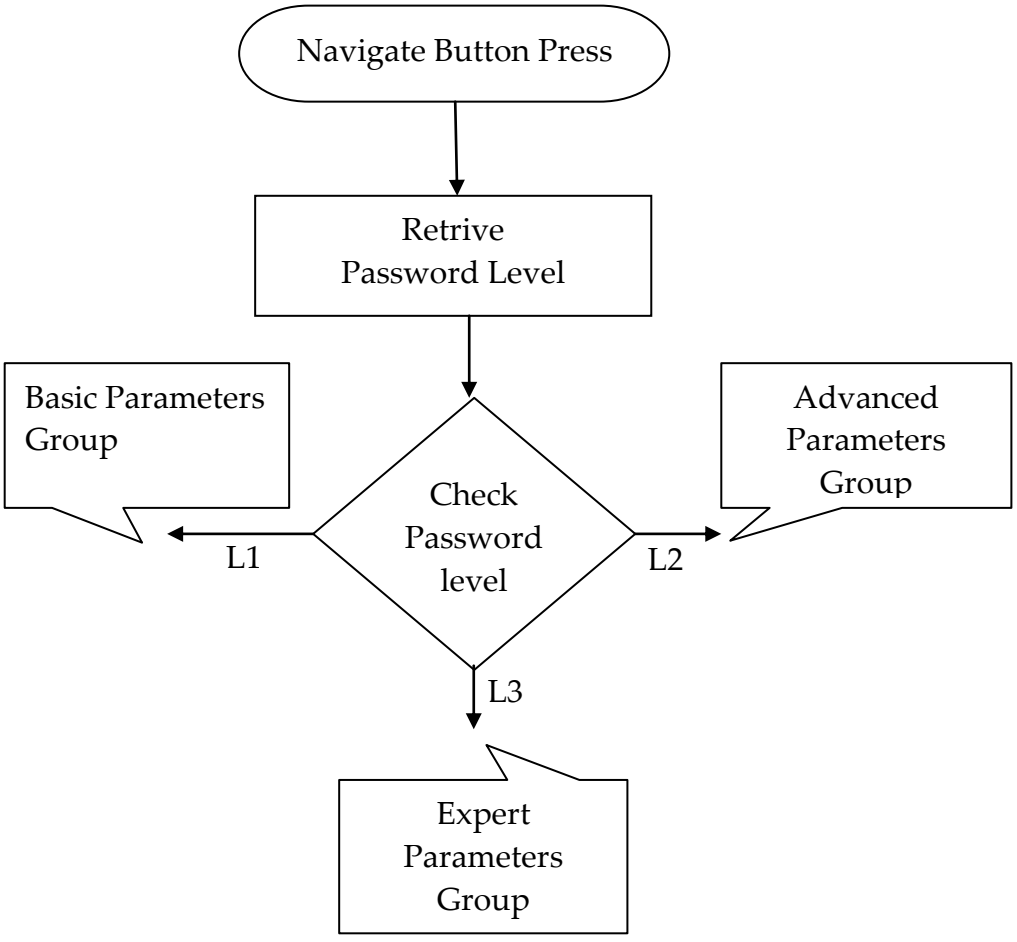
This process is implemented to run continuously with 60secs refresh interval for next occurrence to maintain synchronous data representation. This process is held when processed to the next activity and reloads when the user returns back to this activity.

5.2.8 User Buttons

Three user buttons are implemented on panel activity screen, includes navigation button, start button and stop button.

Navigate Button:

This button press handles to navigate to groups activity, displaying the available parameters divided into groups. These groups are displayed based on three password levels set by the administrator. So, similar behavior is implemented as described in the below flow chart.

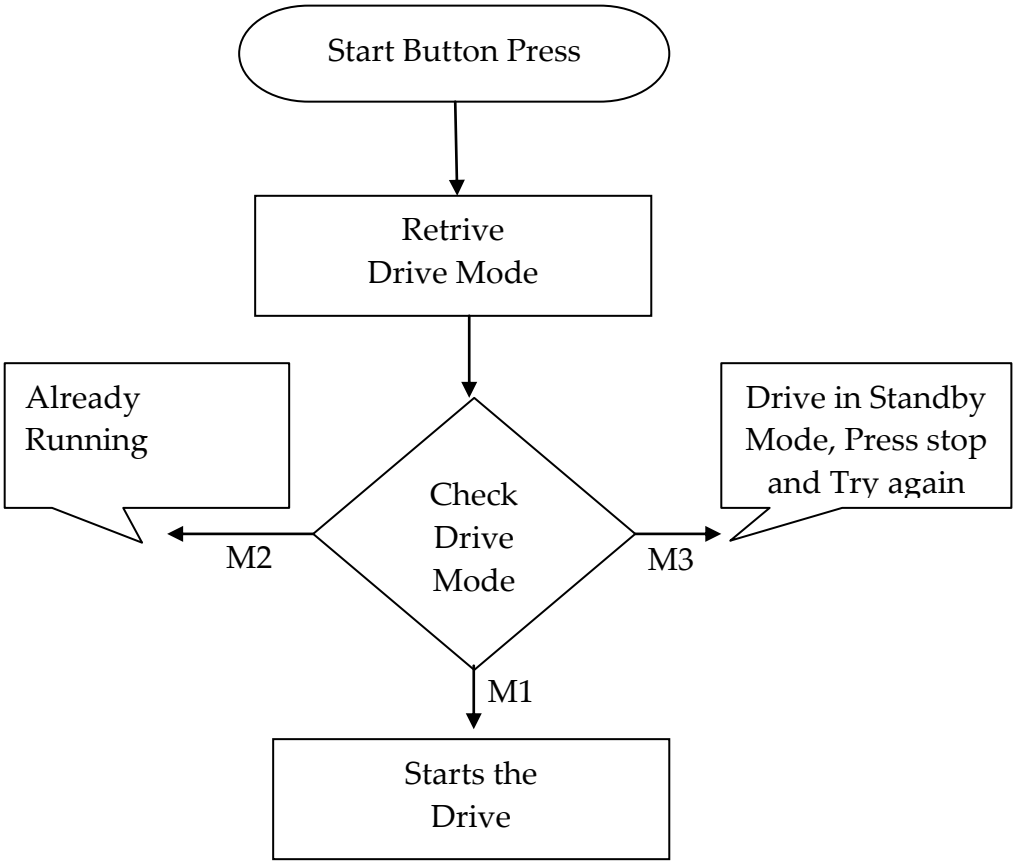


L1 = Password Level 1
L2 = Password Level 2
L3 = Password Level 3

Depending on the password level set by administrator on Smart run the navigate button press checks and presents accordingly the respective visible groups. Display panel activity is kept hold on the navigating button press and reloads after return to that activity.

Start Button:

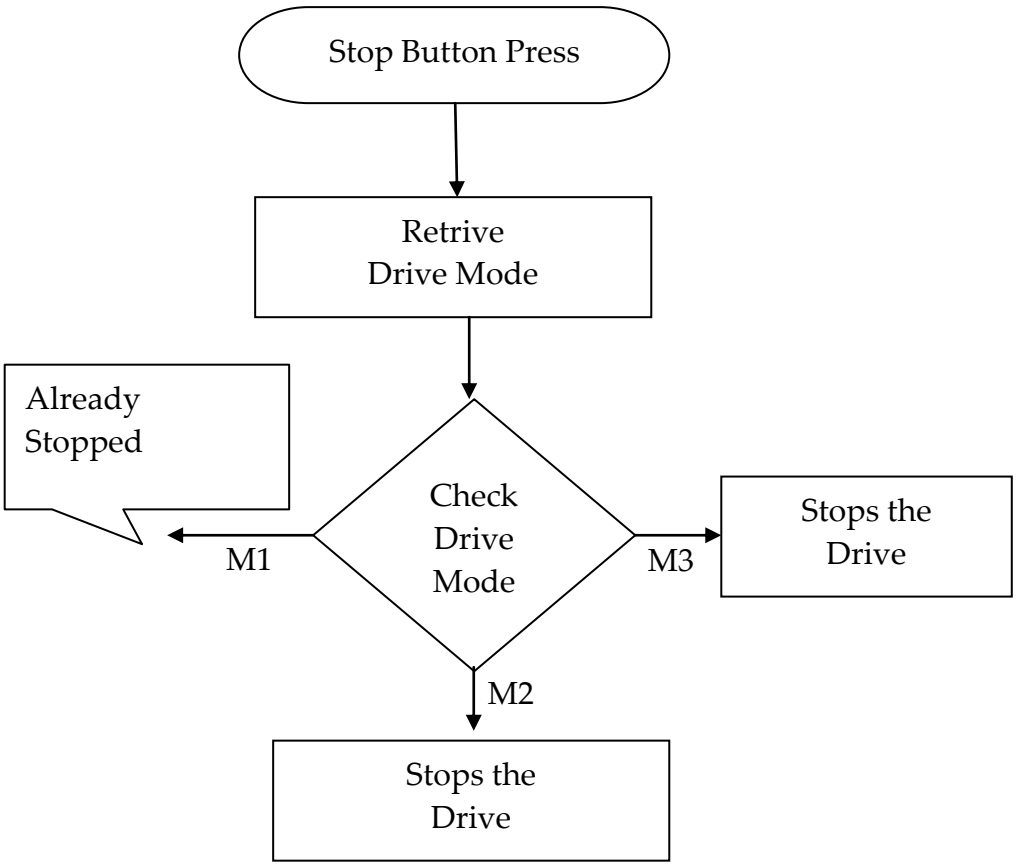
This button press handles the functionalities to start the smart run. This function checks the mode of smart run whether it is in running mode or standby mode or in stopped mode and executes if and only if the drive is in stopped mode.



M1 = Stopped mode
M2 = Running Mode
M3 = Standby Mode

Stop Button:

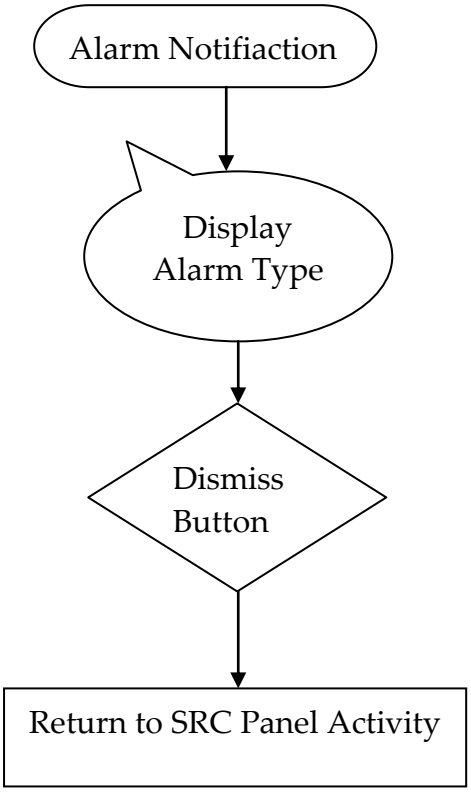
This button press makes the Smart run to stop if it is in running mode or in standby mode.



M1 = Stopped mode
M2 = Running Mode
M3 = Standby Mode

5.2.9 Alarm Monitoring

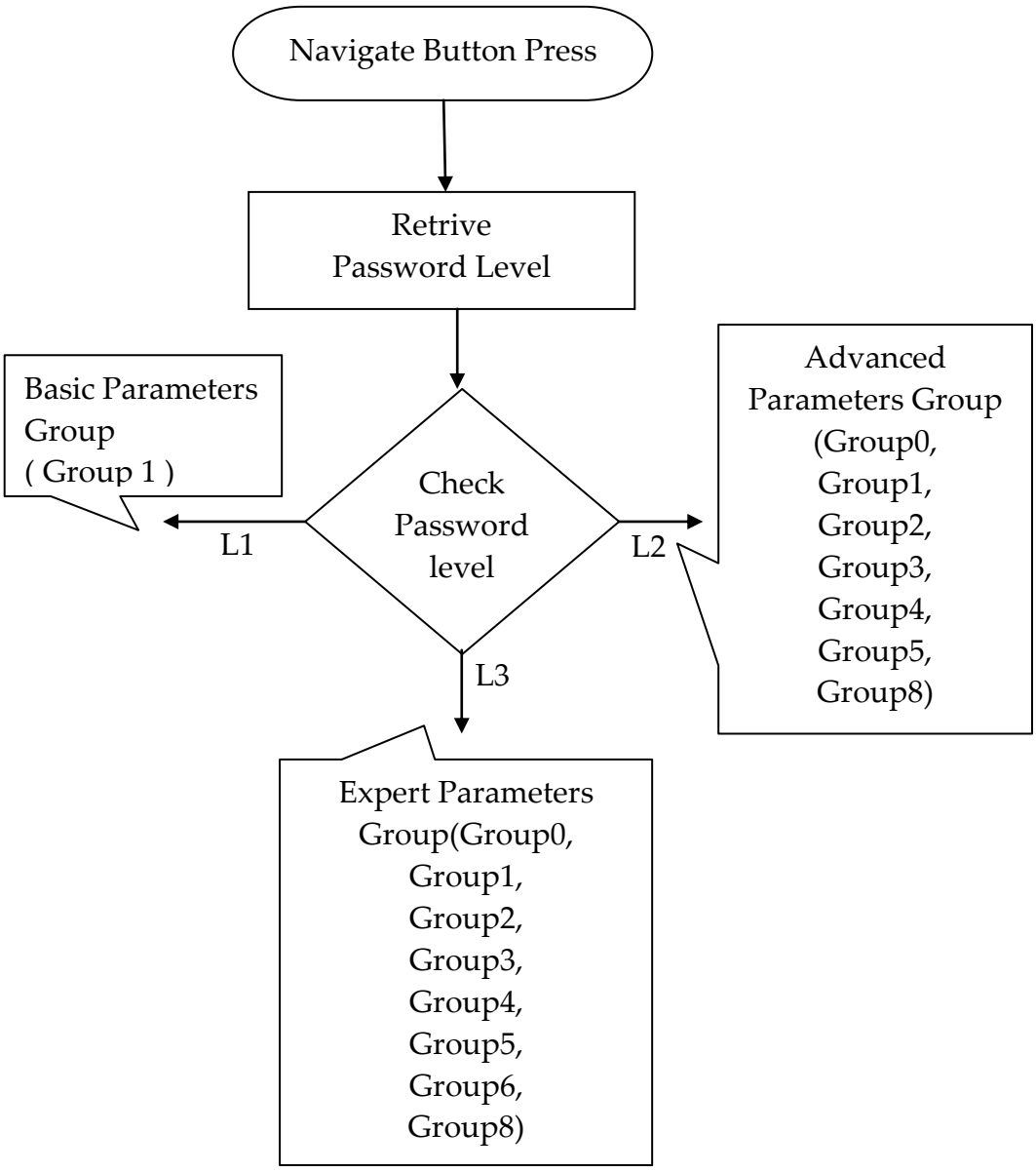
Smart run provides several alarms include Pump leakage, Pump over temperature, High level alarm and Sensor error alarm. All these alarms are implemented in this smart application, these alarms are continuously monitored and notified for every one minute refresh interval to operator when the application detects any alarm state from the smart run.



Dismiss button: This button just closes the alarm notification and returns to SRC panel activity.

5.2.10 Groups Activity

This activity shows different group buttons based on password level settings. Each group consists respective group visible parameters, operator can easily select the corresponding group depending on the parameter to be accessed. Android's Grid View is used for displaying these groups.

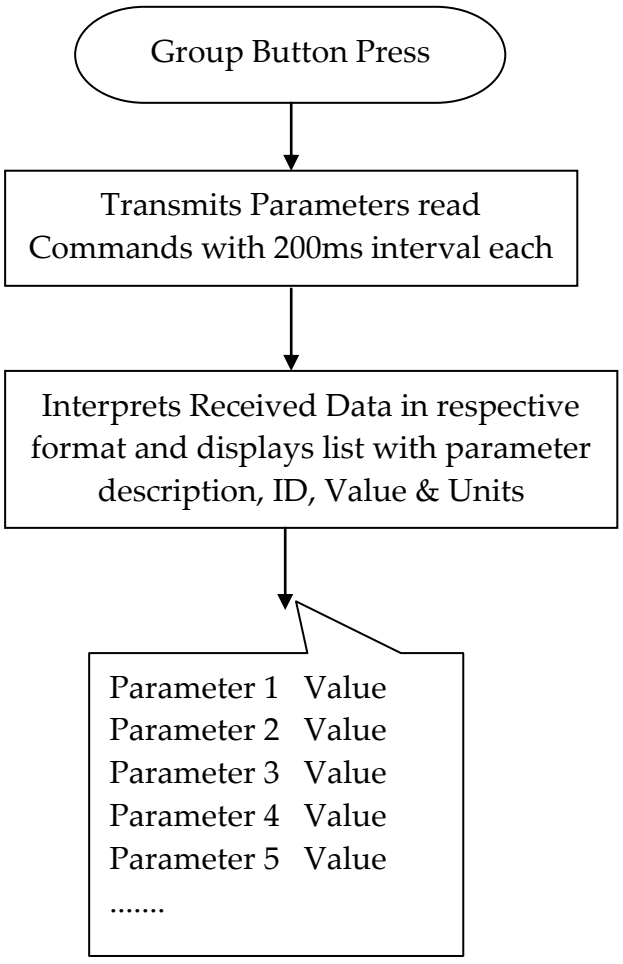

Navigate Button Press
Retrive Password Level
Check Password level
L1
L2
L3
Basic Parameters Group (Group 1)
Advanced Parameters Group (Group0, Group1, Group2, Group3, Group4, Group5, Group8)
Expert Parameters Group(Group0, Group1, Group2, Group3, Group4, Group5, Group6, Group8)

L1 = Password Level 1
L2 = Password Level 2
L3 = Password Level 3

Any of these group button press starts transmitting commands for retrieving the parameters from the smart run. Depend on the password level and the group button pressed respective parameter commands are executed and receives the commands result. These results are appended to one another as the Android receives the data without any boundaries. To the whole data set an algorithm is applied to separate them into an individual parameter message using the end of the message delimiter as reference.

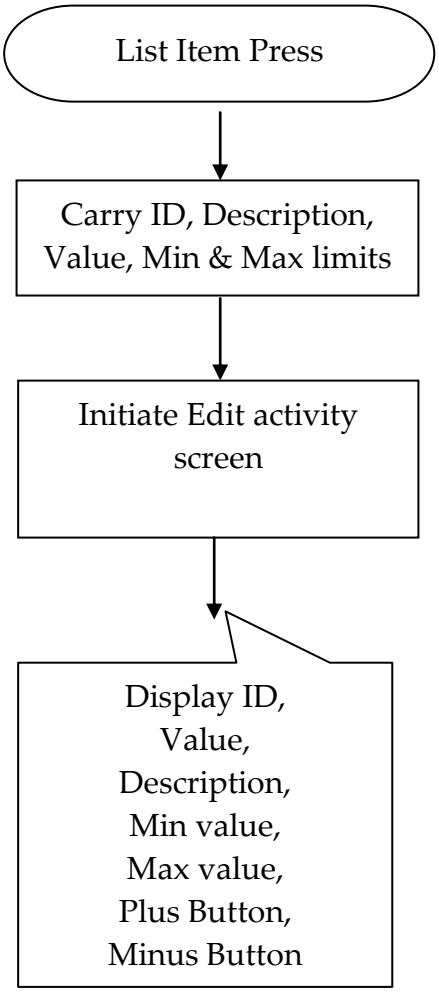
5.2.11 List Activity

In this activity based on the group button press a list of parameters are displayed along with its description, ID, value of the parameter and units of the parameters. Android's List view libraries are used to display these parameters.

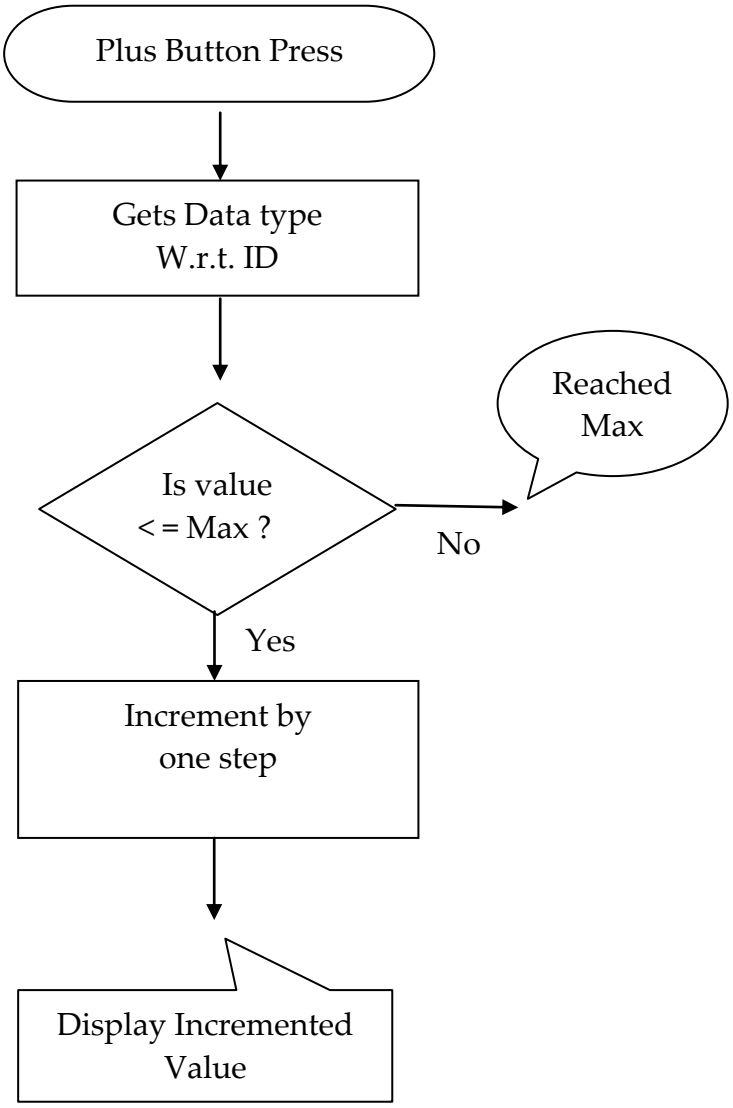

Group Button Press
Transmits Parameters read Commands with 200ms interval each
Interprets Received Data in respective format and displays list with parameter description, ID, Value & Units
Parameter 1 Value
Parameter 2 Value
Parameter 3 Value
Parameter 4 Value
Parameter 5 Value
.....

5.2.12 Edit Parameters Activity

Except group 0 parameters which are read only parameters all other group parameters are editable. Depending on the parameter's type, maximum and minimum limits the parameter's value can be changed in this section. Basically two operations can be performed on the value includes incrementing or decrementing the value. Two buttons, one for incrementing (Plus Button) and another for decrementing (Minus Button) are provided for these actions.

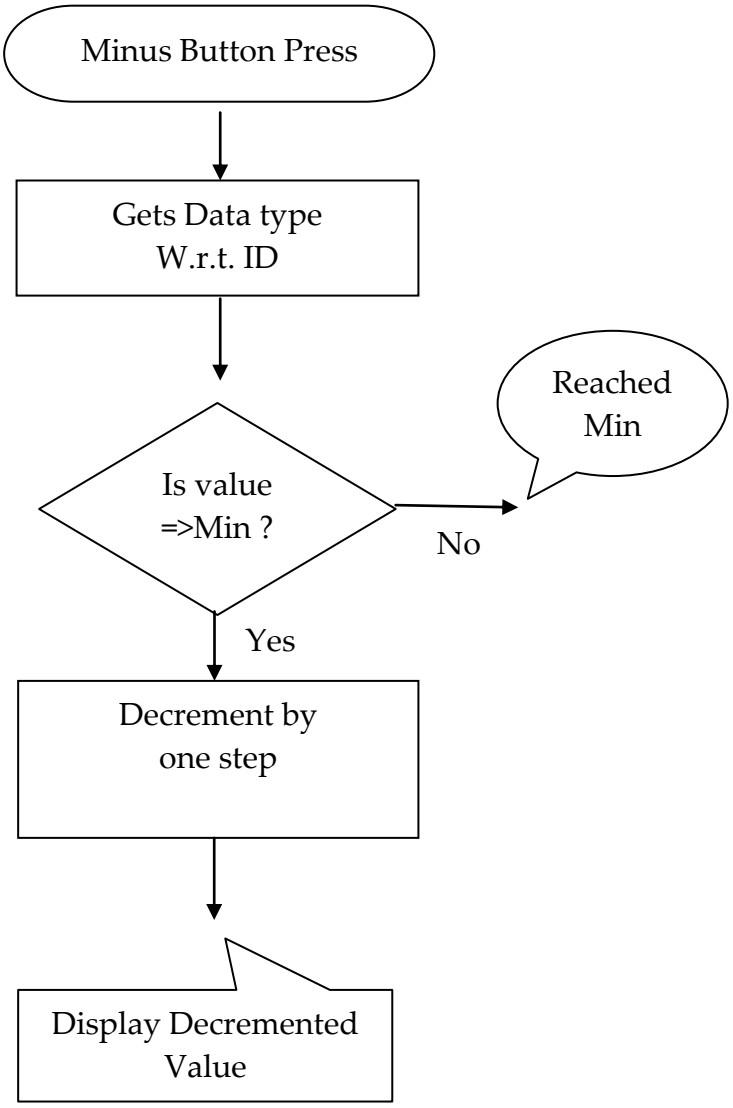


Increment a Value:



The parameter's ID is retrieved from the list view defines the data type of the parameter, the maximum value sets the boundary limits to the parameter. So when the value reaches the maximum possible limit it displays a toast message to the user showing with text as "Reached Max", else the value is incremented by one step according to the data type and displayed the incremented value in the value field.

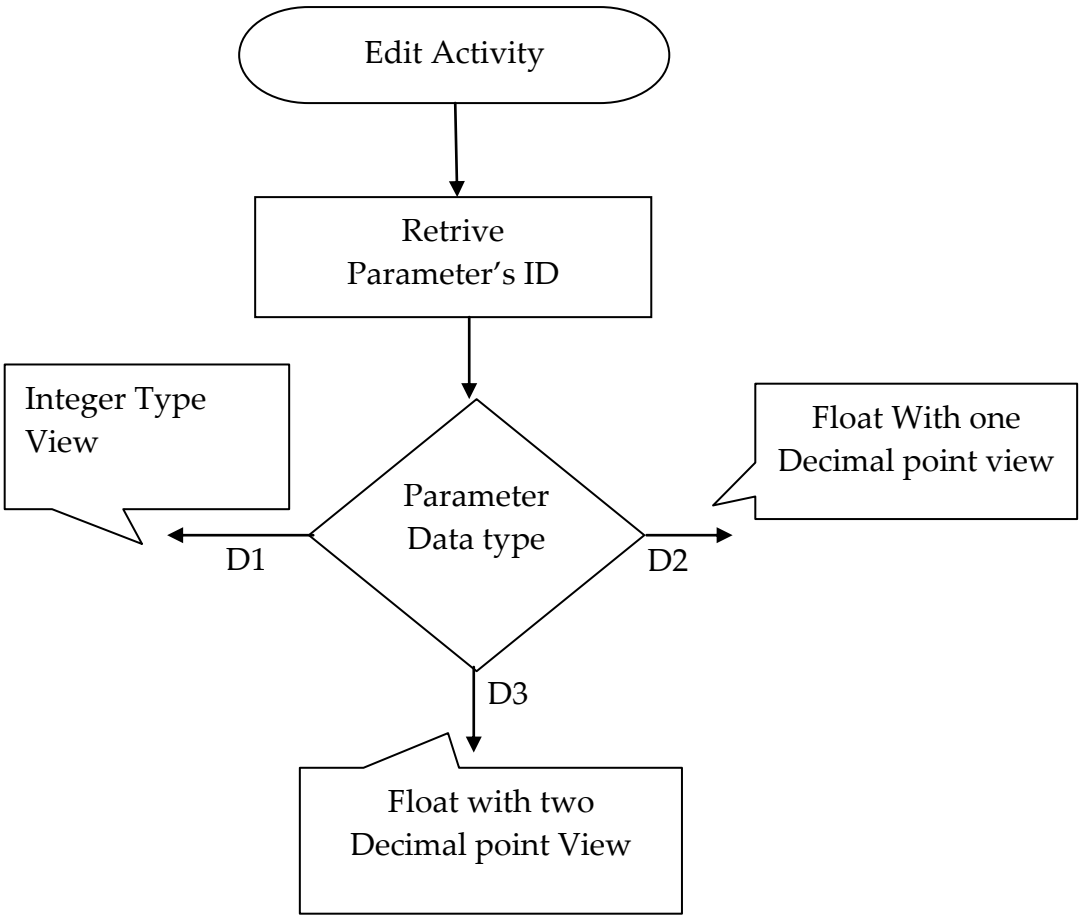
Decrement a value:



On Minus button press the present value is checked with minimum limit and if the value is not => the min limit a toast message is displayed to the user showing with text as "Reached Min", else the value is decremented by one step according to the data type and displayed the new decremented value in the value field.

Data type dependency:

Smart Run has several parameters, each parameter has different data types includes integer type, float type with one decimal point and float type with two decimal points. To differentiate into respective data type a logical approach is followed taking parameter's ID as a key reference. The Android value filed text view is used to display the parameter's value. Depending on the data type the text view is switched to its type to show the appropriate value.



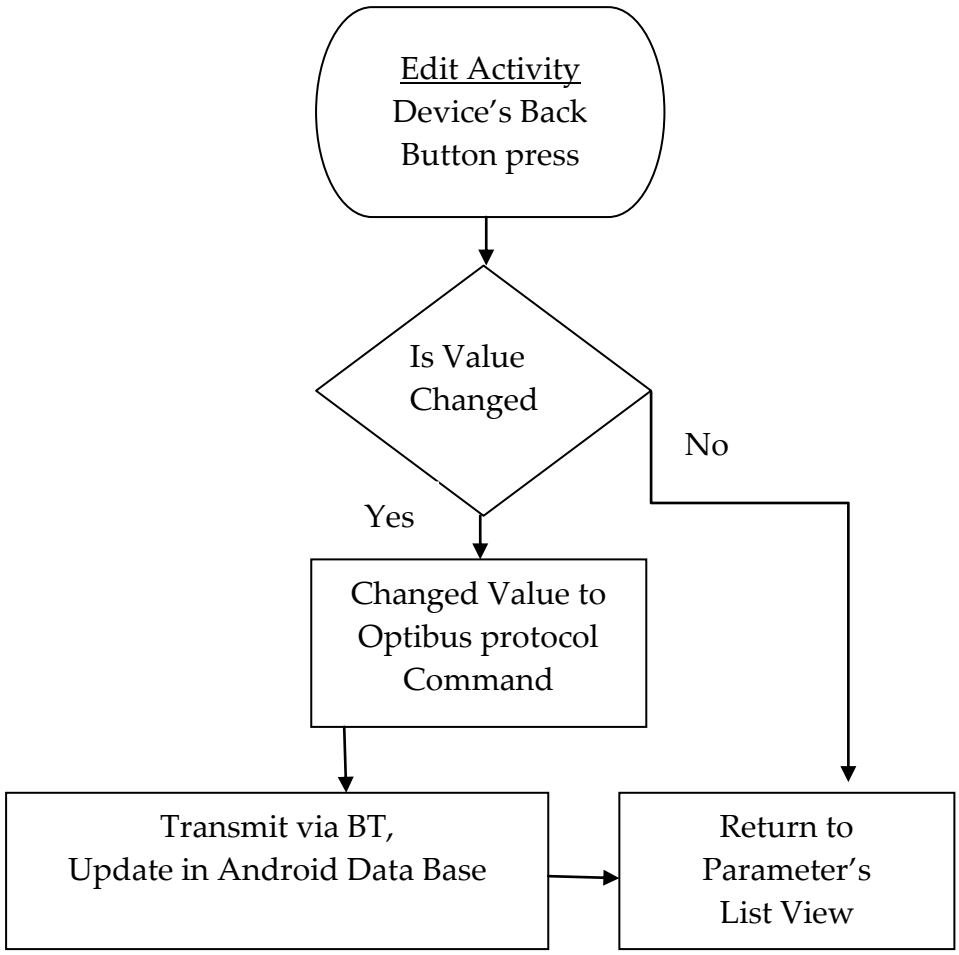
D1 = Integer data type
D2 = Float with one Decimal Point type
D3 = Float with two Decimal Points type

Boundaries for values:

Each Smart run's parameter has minimum and maximum limits, these are defined in android's local resources. These items are designated with address and are accessed by calling the corresponding address. These limit the operator to maintain the same behavior as Smart run. When operator tries to cross these boundaries a toast message is displayed warning with text message showing reached the max/min limits and the value will not change beyond the boundary specifications.

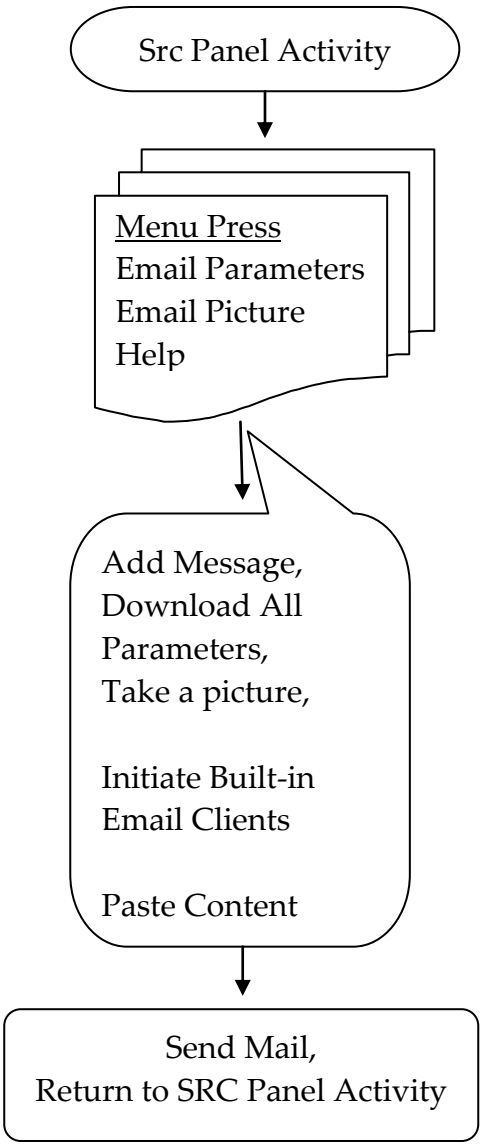
5.2.13 Applying Change in value to SRC over Bluetooth

From Edit Value activity when the operator changes the parameter's value the new changed value applies to the Smart run over Bluetooth. This feature is processed on Android device's back button press.



5.2.14 Support Service

This serves an important feature of this application, Usually in fault cases at pump stations there is no better approach in fault detection at present situations. Considering this a smart support service is included through which the faulty situations are handled in a better and smart procedure. For this solution using Android's Emailing capability is implemented. So, when the operator wishes to contact support service regarding the faulty states, with a simple step all the parameter settings and some text message regarding the problem can be transferred to support service via the android's built-in email client. This feature is included in the device's Menu button during Display panel activity screen.



5.3 Test Platform

For testing purpose a PC HyperTerminal program, Dock light[49] is used, Similar communication functionalities as smart run functionalities are implemented. This program helped in developing a prototype and run tests to check the behavior of application response. A group of commands and their expected results are defined in this software. This program responds corresponding to the query received from the smart phone application. Below snippet shows the program's terminal screen with commands.

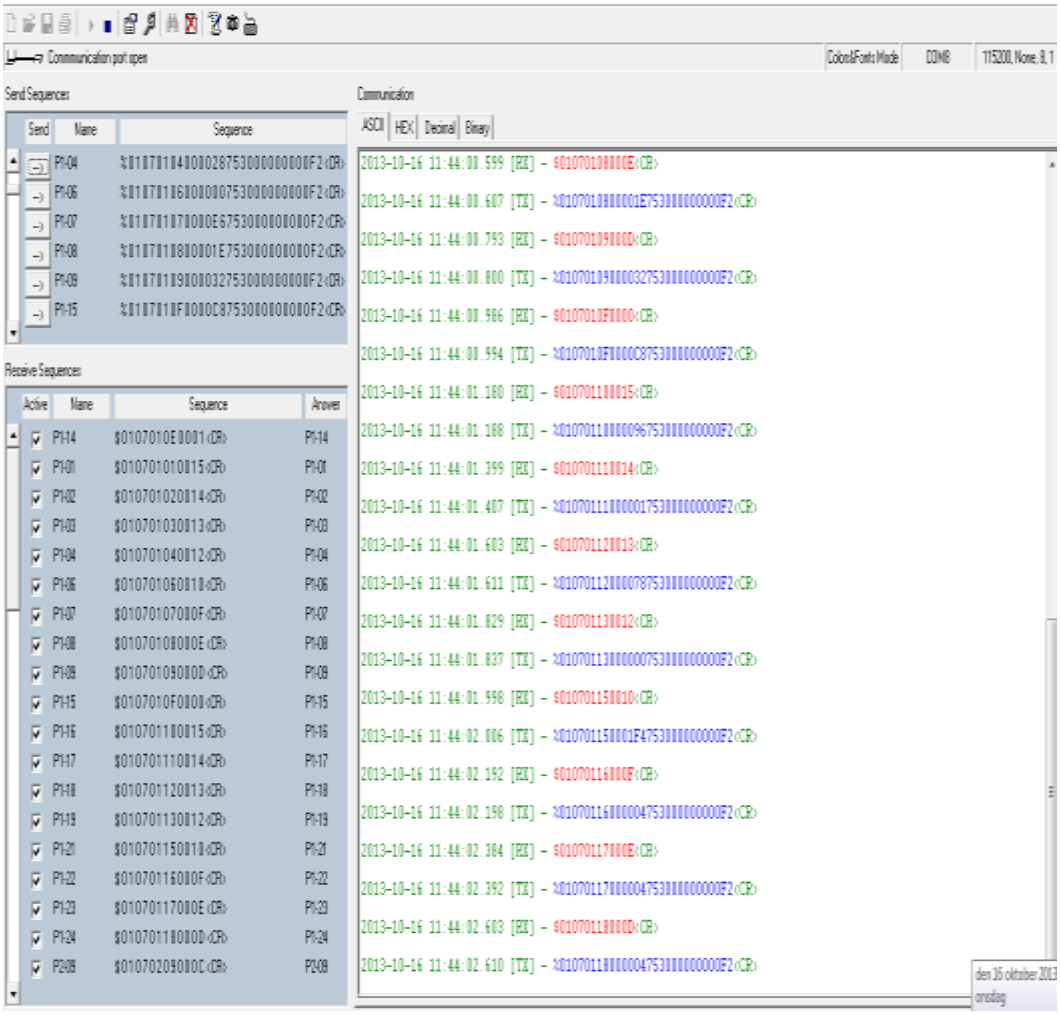


Figure 5.3.1 : Docklight Panel showing commands

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6 Results

An HMI based on Smart phone, that exemplifies how a Smart phone can relay information between a pump drive and an operator in the vicinity of the pump is designed and tested. A brief comparison of wireless technologies, mobile operating systems are presented in below sections 6.1 to 6.3 which were useful in decision making in platform selection and future possibilities for other pump products. Later section 6.4 about performance analysis in retrieving the data and sections 6.5 till 6.14 shows prototype application results.

6.1 Wireless Communication Comparisons

6.1.1 Classic Bluetooth VS BLE

Category	Classic Bluetooth	Bluetooth Low Energy
Standardization Body	Bluetooth SIG	Bluetooth SIG
Range	~10m(Class II)*	~50m
Frequency	2.4-2.5Ghz	2.4-2.5Ghz
Bit Rate	1-3Mbit/S	~200 Kbit/S
Set-up Time	<6S	<0.003S
No. Of Channels	79	40
Channel Bandwidth	1Mhz	2Mhz
Availability in smart phones	Most smart phones	Latest smart phones
Cost**	1$/pc	1$/pc

Table 6.1-1 : Classic Bluetooth Vs Bluetooth Low Energy. [17]

* Here Class II range is compared as most smart phones are equipped with this Class.

** Estimated cost for radio when purchased in hundreds of units.

6.1.2 Bluetooth Vs Wi-Fi Direct Vs NFC

Category	Classic Bluetooth	BLE	Wi-Fi Direct	NFC
Distance	10m*	50m	200m	0.04m
Transmission Speed	1Mbps	200Kbps	250Mbps	424Kbps
Frequency	2.4 GHz	2.4 GHz	2.4GHz	13.56MHz
Setup –Time	< 6s	<0.003s	< 3s	< 0.1s
Hardware Cost	Normal	Normal	High	Low
Coin –Cell Powered	Months	Years	Days	Years
Power Con-sumption	2.5mW	0.147mW	0.210 W	0.165mW

Table 6.1-2 : Comparisons between Bluetooth, Wi-Fi Direct and NFC. [22]

* Here Class II classic Bluetooth is taken into considerations as in practical most smart phones are equipped with this class.

6.2 Smart Phone OS and their Bluetooth possibilities

6.2.1 Android OS version and Bluetooth possibilities

Starting with the first release from October 2008 android has released several updates to its devices. Below table shows the version history of android operating system[30] :

Version	Name	Bluetooth Version	Third party Communication
4.4	Kitkat	BLE	Yes
4.3	Jelly Bean	BLE	Yes
4.2.x	Jelly Bean	Classic BT	Yes
4.1.x	Jelly Bean	Classic BT	Yes
4.0.x	Ice-cream Sandwich	Classic BT	Yes
3.2	Honeycomb	Classic BT	Yes
3.1	Honeycomb	Classic BT	Yes
2.3.3-2.3.7	Gingerbread	Classic BT	Yes
2.3-2.3.2	Gingerbread	Classic BT	Yes
2.2	Froyo	Classic BT	Yes
2.0-2.1	Eclair	Classic BT	Yes
1.6	Donut	NA	NO
1.5	Cupcake	NA	NO
1.1	Alpha	NA	NO
1.0	1.0	NA	NO

Table 6.2-1 : Google Android's Version History

6.2.2 iOS version history and Bluetooth possibilities

iOS Version	Model	Bluetooth Version	Third party Communication
iOS 1.0	iPhone 1G	Classic BT	Requires MFI Certification
iOS 2.0	iPhone 3G	Classic BT	Requires MFI Certification
iOS 3.0	iPhone 3GS	Classic BT	Requires MFI Certification
iOS 4.0	iPhone 4	Classic BT	Requires MFI Certification
iOS 5.0	iPhone 4S	BLE 4.0	Yes With BLE Chips
iOS 6.0	iPhone 5	BLE 4.0	Yes With BLE Chips
iOS 7.0	iPhone 5C,5S	BLE 4.0	Yes With BLE Chips

Table 6.2-2 : iOS Version History and Bluetooth Posibilities[36]

6.2.3 Windows OS version history and Bluetooth possibilities

Windows OS Version	Bluetooth Version	Third party Communication
Windows phone 7	Classic BT	Yes
Windows phone 8	Classic BT	Yes

Table 6.2-3 : Windows OS version History and Bluetooth Possibilities[40]

Bluetooth low energy chips have arrived with windows phone 8 includes latest Nokia Lumia devices, Microsoft has released API's supporting Bluetooth Low Energy opening doors to develop applications using BLE 4.0 standards.

6.3 Mobile OS Features Comparisons

Feature	*Android*	*iOS*	*Windows OS*
App Dev	Free	99 $/year	Free
App Publishing	25 $ one time	Included in Dev	99 $/year
Trend	High	Medium	Low
Battery	Depends on Set(>iOS)	Limited(1440 mAh)	Depends on Set
Bluetooth	Yes	Yes*	Yes
NFC	Yes	No	Yes
Wifi-Direct	Yes(Latest)	No	Yes(few)
Web-Based	Yes	Yes	Yes
Developer Software OS Requirements	Windows/Linux	Mac OS	Windows
To Find Developers	Easy	Easy	Few
Relation to Xylem	Not Currently	Yes	Not Currently

Table 6.3-1 : Different Mobile OS Features Comparisons

*Requires MFI Certification

Considering market trends, features and people's interest into account only three major Mobile OS are compared, and other OS like Symbian, bada, blackberry were omitted from comparisons.

6.4 Performance Analysis

6.4.1 Time to setup connection

Bluetooth Scanning = maximum 12 seconds (Total Discovery process)
Connecting device = < 3s

6.4.2 Time to Retrieve Smart Run Parameters

Two different lengths of data response are possible from the pump drive. Using single parameter access command, result data length is 30 bytes and using multiple parameter access command, result data length is 42 bytes.

Using Single parameter access: Result length -30 bytes

Interval = Minimum time to get reply back(150ms) + Short delay

Test	Interval(ms)	Minimum delay observed
1	150 + 10= 160 ms	Insufficient
2	150 + 20= 170 ms	Insufficient
3	150 + 30= 180 ms	Insufficient
4	150 + 40= 190 ms	Moderate
5	150 + 50= 200 ms	Sufficient

Using Multiple parameter access: Result length - 42 bytes

Interval = Minimum time to get reply back(150ms) + Short delay

Test	Interval(ms)	Minimum delay observed
1	150 + 150 = 300 ms	Insufficient
2	150 + 200 = 350 ms	Insufficient
3	150 + 250 = 400 ms	Insufficient
4	150 + 300 = 450 ms	Moderate
5	150 + 350 = 500 ms	Sufficient

Single parameter : 200ms
Multiple parameter : 500ms

Total time :
Using single parameter access = No. of Parameters * 200ms
Using Multiple parameter access = No. of Parameters * 500ms

Multiple access commands provide eight parameter values to speed up the communication process, but they are accessed in series from the registers. In this application the required parameters to be displayed are scattered in different location registers. Hence even using multiple parameters access command it is necessary to send similar number of commands to access the required parameters as in case for individual parameter access. Also for group 0 parameters it is not provided to access those registers using these special multiple read commands.

6.5 Login Activity

User Fields are provided for secured authorized usage. Operator can enter the credentials provided by the company[4] to access the application.

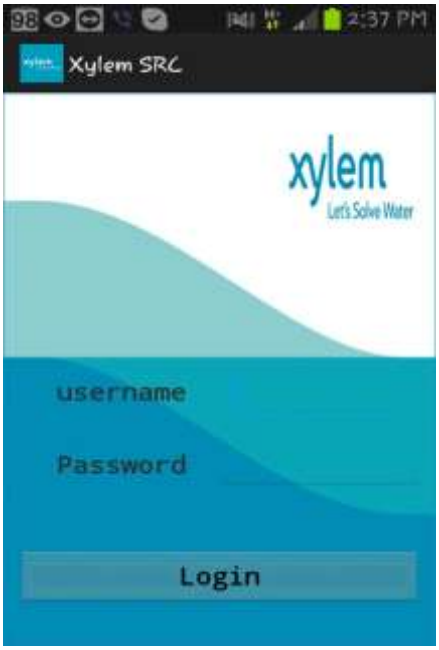

Figure 6.5.1 : Login Activity Screenshot

6.6 Change Language

User Selectable language switching options to support different languages can be chosen from device[5] menu button press and selecting change language from the dropdown list.

[4] Xylem Water Solutions AB
[5] Smart Phone

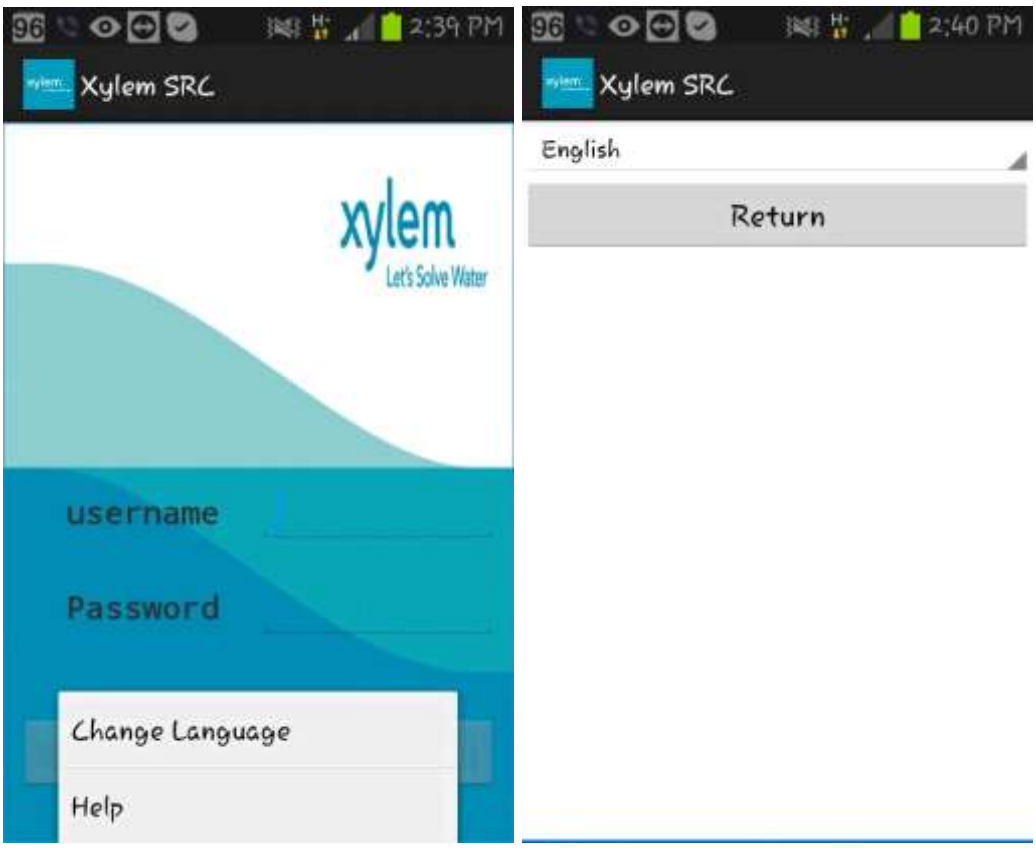

Figure 6.6.1 : Change Language Activities Screenshot

To show a working prototype model presently supports for two languages include English and Swedish are provided, and as Android smart phones have no limitations on languages endless multilingual support can be developed.

Figure 6.6.2 : Login Activity in Swedish Screenshot

6.7 Select Activity

Choice to select connection setup for SRC and Dewatering pumps.

Figure 6.7.1 : Select Activity in English Screenshot

Figure 6.7.2 : Select Activity in Swedish Screenshot

6.8 Connection Setup with SRC

6.8.1 Bluetooth Permission Request

Prompts user[6] permission to turn on Bluetooth to setup a connection over Bluetooth.

Figure 6.8.1 : Bluetooth Permission Request Screenshot

[6] Operator

6.8.2 Scanning for Smart Run's Bluetooth device

Figure 6.8.2 : Scanning Results for BT devices Screenshot

Upon permitting to use Bluetooth by user[7], Application performs a quick scanning of Bluetooth devices and a list of available Bluetooth devices with in the vicinity is provided. From the results list user can select an item to setup a connection with the respective device.

[7] Operator

6.9 SRC Panel Activity

After successful connection setup the application transmits commands to see the status of smart run and displays the corresponding mode on the panel activity. This activity view is designed to represent same as a real Smart Run unit for providing similar experience work environment. The drive status is retrieved frequently with an interval of 60 seconds. So, for every one minute this activity is refreshed with current status of smart run. Below screenshots shows three states of smart run. Also start/stop buttons are provided to control the smart run from the application.

6.9.1 SRC Stop Mode

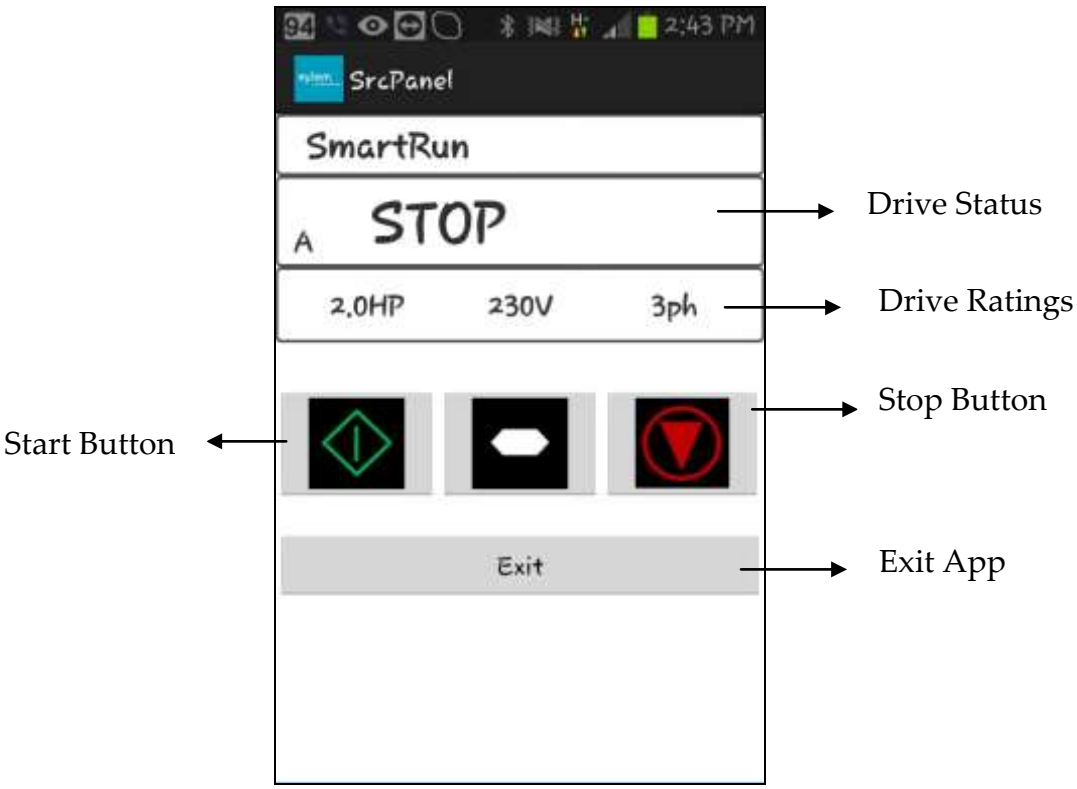

Figure 6.9.1 : SRC in Stop Mode Screenshot

6.9.2 SRC Run Mode

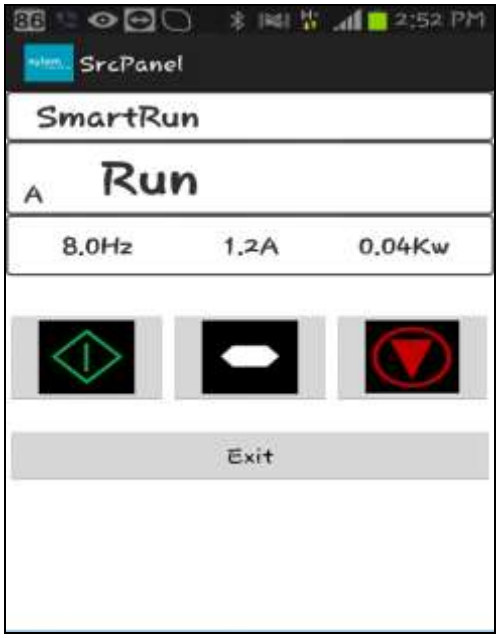

Figure 6.9.2 : SRC in Run Mode Screenshot

6.9.3 SRC Standby mode

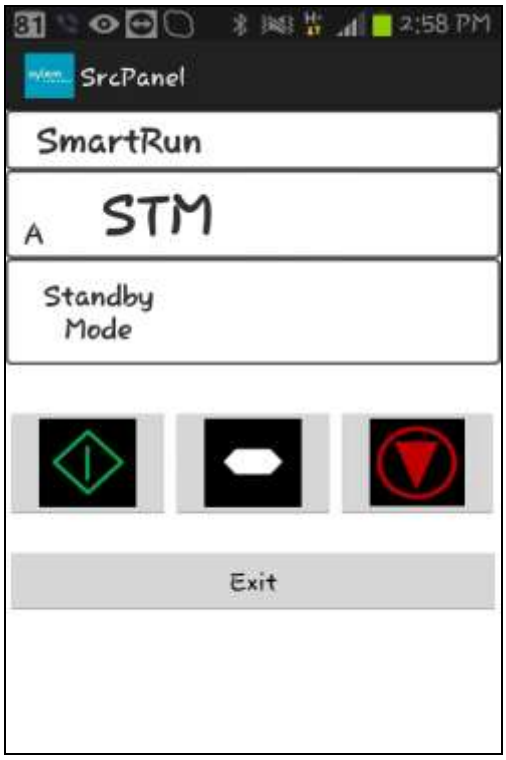

Figure 6.9.3 : SRC in Standby Mode Screenshot

6.10 Support Service

Figure 6.10.1 : SRC Panel Activity's Menu Dropdown list Screenshot

On the menu button press in SRC panel activity popups a dropdown list with several options for emailing parameters or to email a picture of the scenario at the pump station.

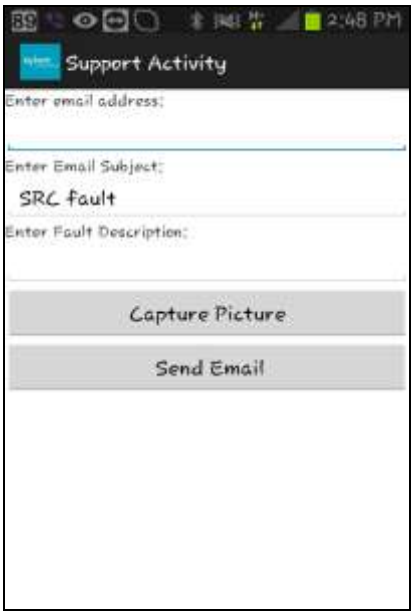

Figure 6.10.2 : Email Picture Activity Screenshot

Figure 6.10.3 : User Choice to use Built-in Email Clients Screenshot

Capture picture button press initiates the mobile device's[8] camera to take a picture, thus the user can take a picture of any faulty situations or the wiring connection on the smart run and send to support sections. Send email button press initiates a dialog box suggesting the user to choose available built-in email clients to send email. Also user fields are provided to enter the fault description to give an overview of the situation or faulty condition to the support people for better service and quick solution.

[8] Smart Phone

6.11 Alarm Monitoring

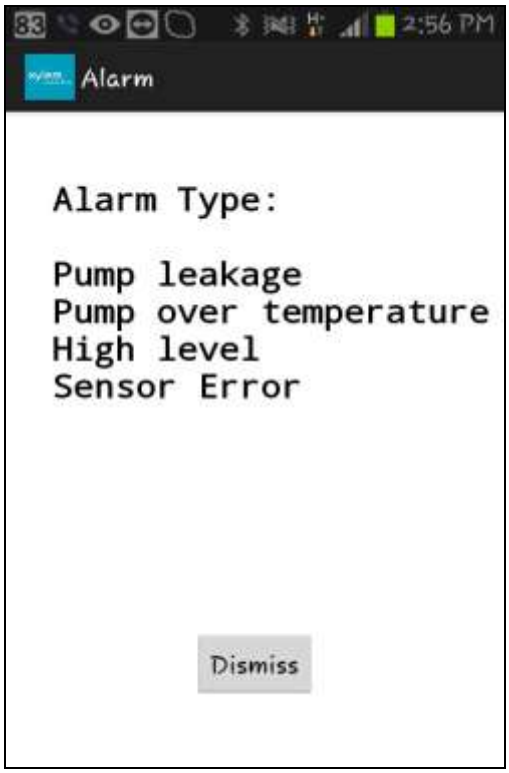

Figure 6.11.1 : Alarm Activity Screenshot

During SRC Panel Activity application frequently[9] checks for any alarm has risen. Smart run has several alarm states[10] each corresponding to specific situations, if an alarm is raised alarm activity pops up displaying the type of alarm based on an alarm level with a warning ring sound and alerts the user to perform the required action continuously until the problem has fixed.

[9] One minute
[10] Refer Appendices C

6.12 Groups Activity

6.12.1 Advanced group level parameters

Figure 6.12.1 : Groups Activity Screenshot

On SRC panel activity's navigate button press, the application checks for the password level set of smart run and corresponding groups are displayed. Three password level's groups are shown accordingly includes basic, advanced and extended parameter groups. Above Figure 6.12.1 shows the groups showing advanced level groups. User can select any of the group button to show their parameters. On selecting group button group of commands are transmitted over Bluetooth to smart run, thereby received respective resultant message is interpreted and forms a list of parameters displaying the parameter id, description and its value with units. A dialog box with text showing loading parameters dialog is displayed during the retrieval process for users to wait till the process is completely executed. Below screen shots show the group's parameters list view.

6.12.2 Wait process Dialog

Figure 6.12.2 : Wait Dialog Screenshot

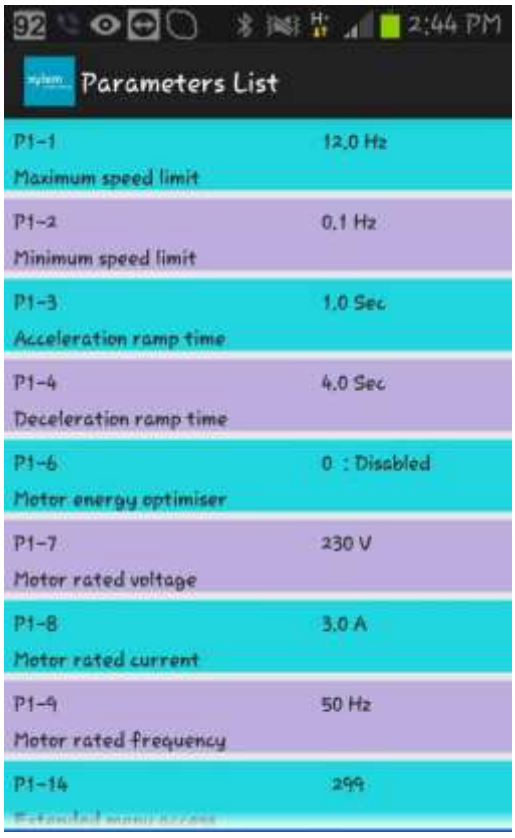

Figure 6.12.3 : Group 1 Parameters list Screenshot

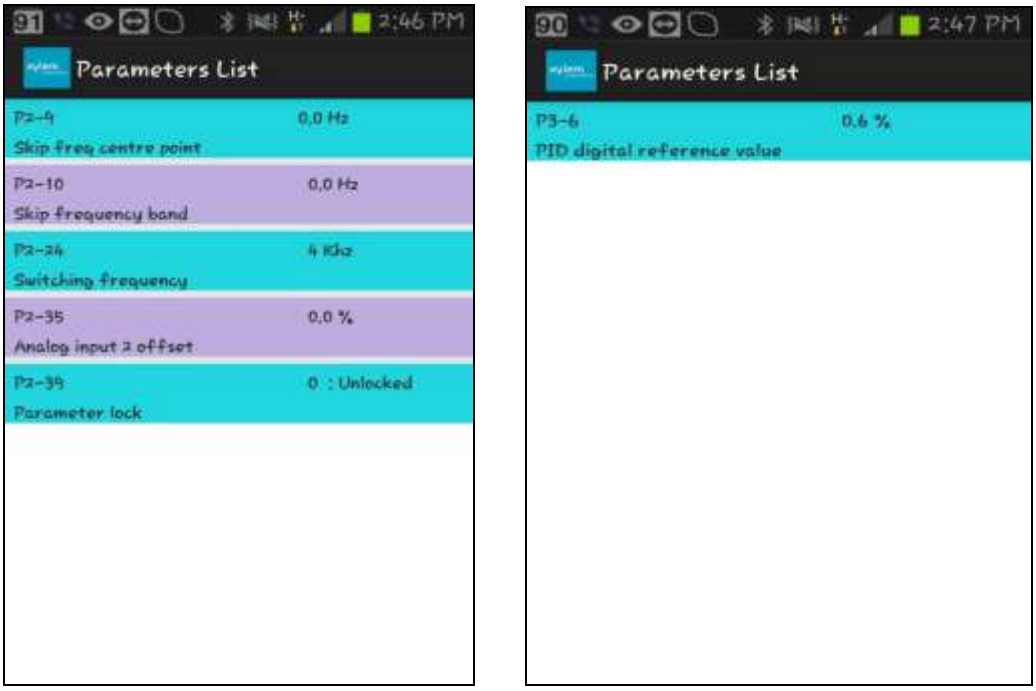

Figure 6.12.4 : Group 2 & 3 Parameters List Screenshots

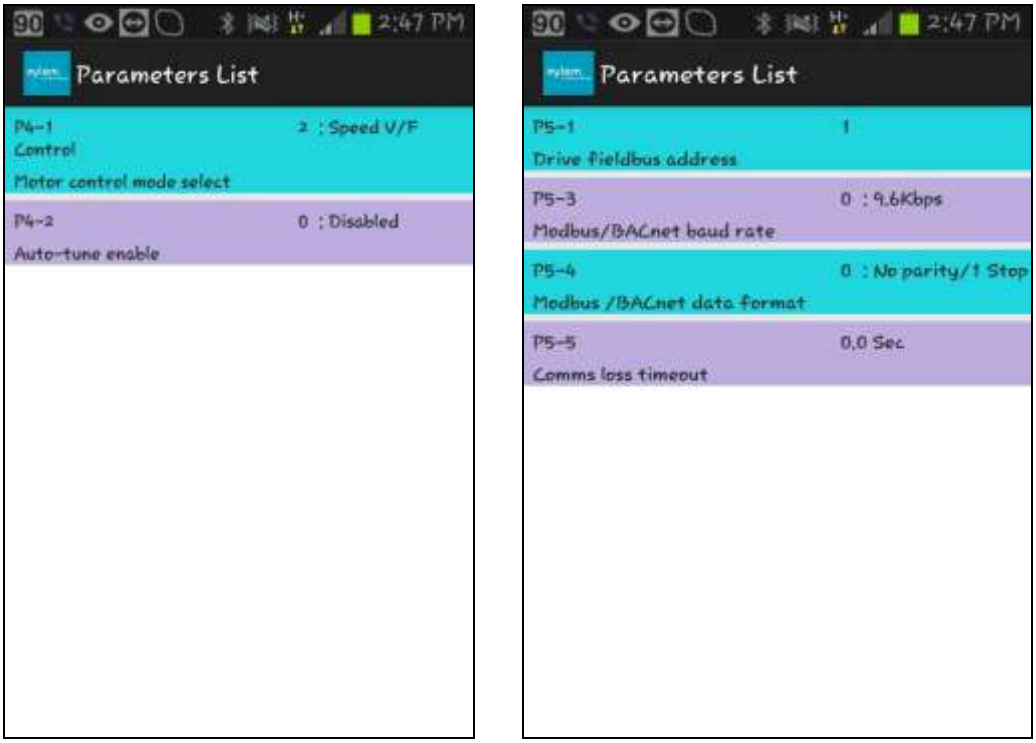

Figure 6.12.5 : Group 4 & 5 Parameters Screenshots

6.13 Edit Value Activity

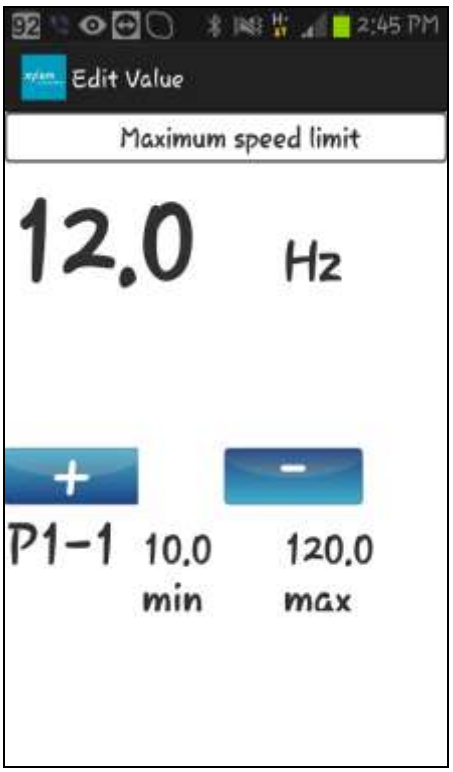

Figure 6.13.1 : Edit Parameter Value Activity Screenshot

From list view activity user can select any of the list items to change its value. In this edit value activity parameter's id, description, value, units, minimum and maximum values are displayed. Two user button plus and minus buttons are provided to increase or decreasing the parameter value. When user tries to increment or decrement a value the application checks for the boundaries of the parameter and warns the user if tries to cross the predefined boundaries. Here as there are several parameters with different type of data types are available parameter's id is taken into consideration and corresponding data type increment and decrements are processed.

To reduce the writing operations, updating the value is performed on device back button press. On back button press the value is checked if it has changed from original value or not and then process writing to smart run only if the value is changed.

6.14 Dewatering Pumps Activity

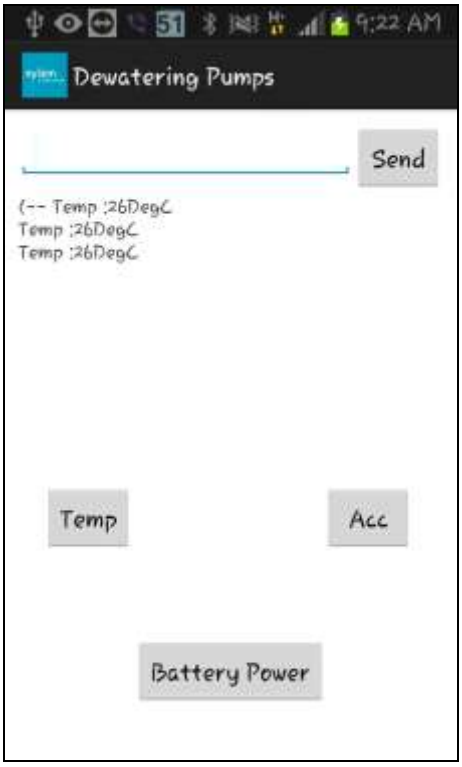

Figure 6.14.1 : Dewatering Pumps Activity Screenshot

This activity corresponds to dewatering pumps applications, from select activity choosing dewatering initiates the Bluetooth scanning process same as seen in smart run connection setup section 6.8. In this case the host is an electronic hardware placed inside the pump developed in parallel with this thesis by another colleague.

This application acts as a receiver section for the developmental hardware, it receives the logged data transmitted by the host and displays over the screen. Also some user buttons are provided in order to make a request to access particular details on interest from the host.

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7 Conclusion

A HMI solution between a operator and a pump drive based on a smart phone is designed and developed, which serves as a simple and cost effective communication platform to communicate with pump drives. This approach showed several advantages includes solving language barriers, alarm notification with the possibility of showing additional information and for dewatering pumps this application serves an important usage acting as a display unit. Also the solution of this thesis work showed a simple and advanced support service to the customers using service options offered through this smart phone application.

I think the task has been solved in an honourable way and with successful methods. I have been able to keep to the time plan on reaching the goals step by step. It has been very beneficial that the users and developers of these pump drives have been so interested in the app. In this competing world, development of the proposed application made Xylem to compete with similar applications in the market with its competitors, thereby helpful to develop interest in Xylem products and services. Therefore, this thesis work was helpful in developing knowledge to the organization about mobile applications, different mobile operating systems and wireless communication options within smart phones. The result seems realistic and useful according to my knowledge, and it will be a sound foundation for further research in this area.

Recommendations : As a proof of concept a prototype working application is designed. For a complete product release it is interested to look after several constraints which can be improved further. For example, the application layout, user interface can be improved more as per user requirement to provide ease of access. Enhance Security of the application usage, a new security layer can be implemented in Optisitck (Bluetooth Transceiver) which makes the application usage more secure. Also different approaches can be followed in retrieving the smart run's parameters to increase speed of presenting parameters in application.

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8 Future Scope

As it is learnt that smart phone applications may serve as a cost effective HMI solution , it is interested to develop Mobile Apps for other Xylem pump controllers and pump drives, with the addition of wireless capability (Bluetooth) to the controllers. Presently the application uses short range wireless communication, i.e. Bluetooth. It would be advantageous to provide other connectivity options using Web Based feature of android system with which user can monitor and configure from anywhere via internet connections within the same app, provided the external gateway near the smart run. This remote accessing feature shall increase the usability, pump drives can be monitored more often, thus can problems in the pump stations be discovered earlier and the risk of pump damage is decreased.

Presently, only textual information is being displayed, even advanced graphical representation of data can be designed. A Single Xylem Application can be developed includes services like Monitor and Control (Xylem SRC-Proposed Application), Xylect Mobile, Xylem Application, Drive Software updates, PLC in Smart Run (Future Application). Pump service recommendations can be provided within the application based on running time and energy data. User guide, videos, application notes can be provided in the application to train the operator to work efficiently. Also, application for Apple iOS provided BLE Optistick and for Windows Mobile OS would be interested to develop.

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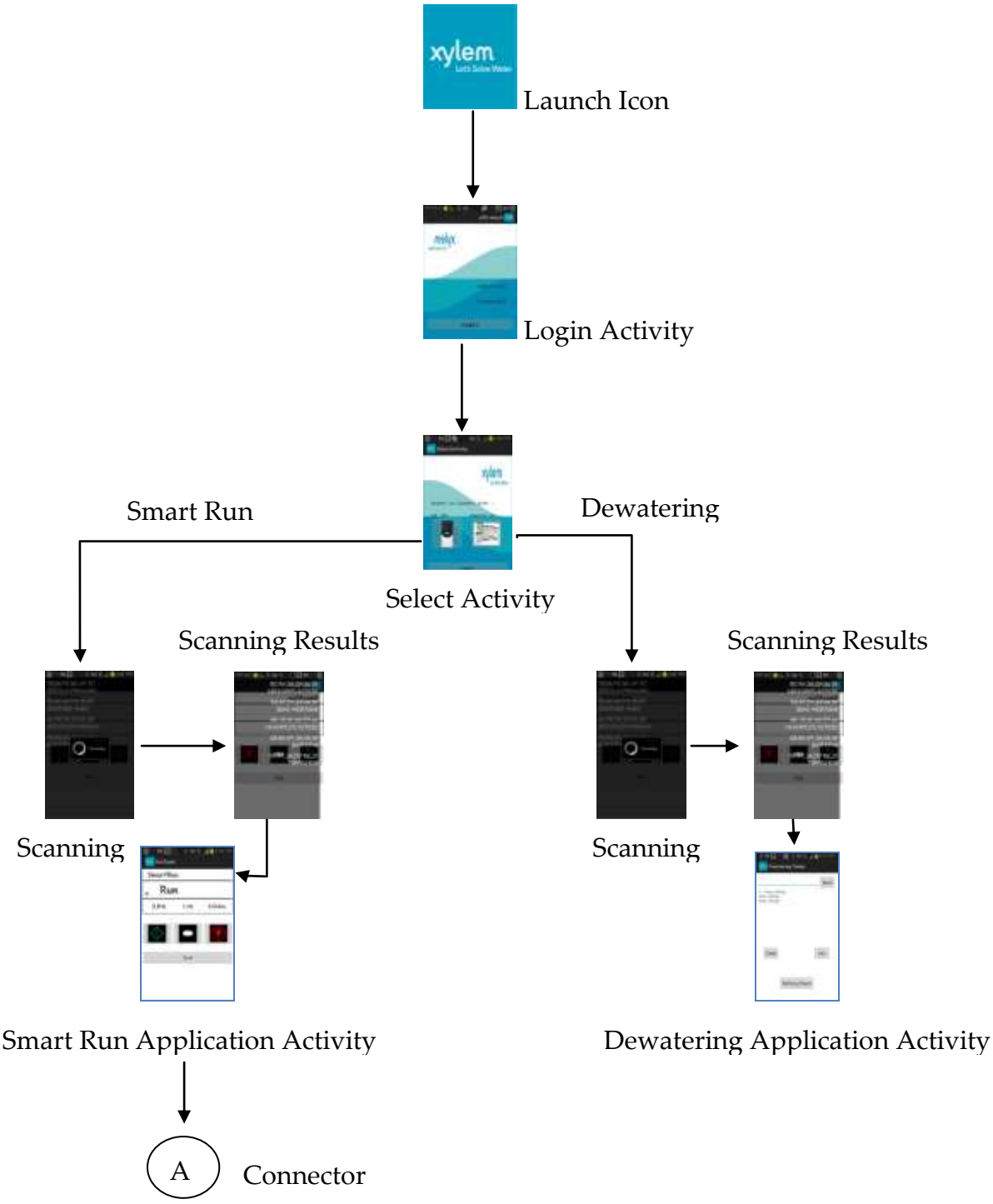
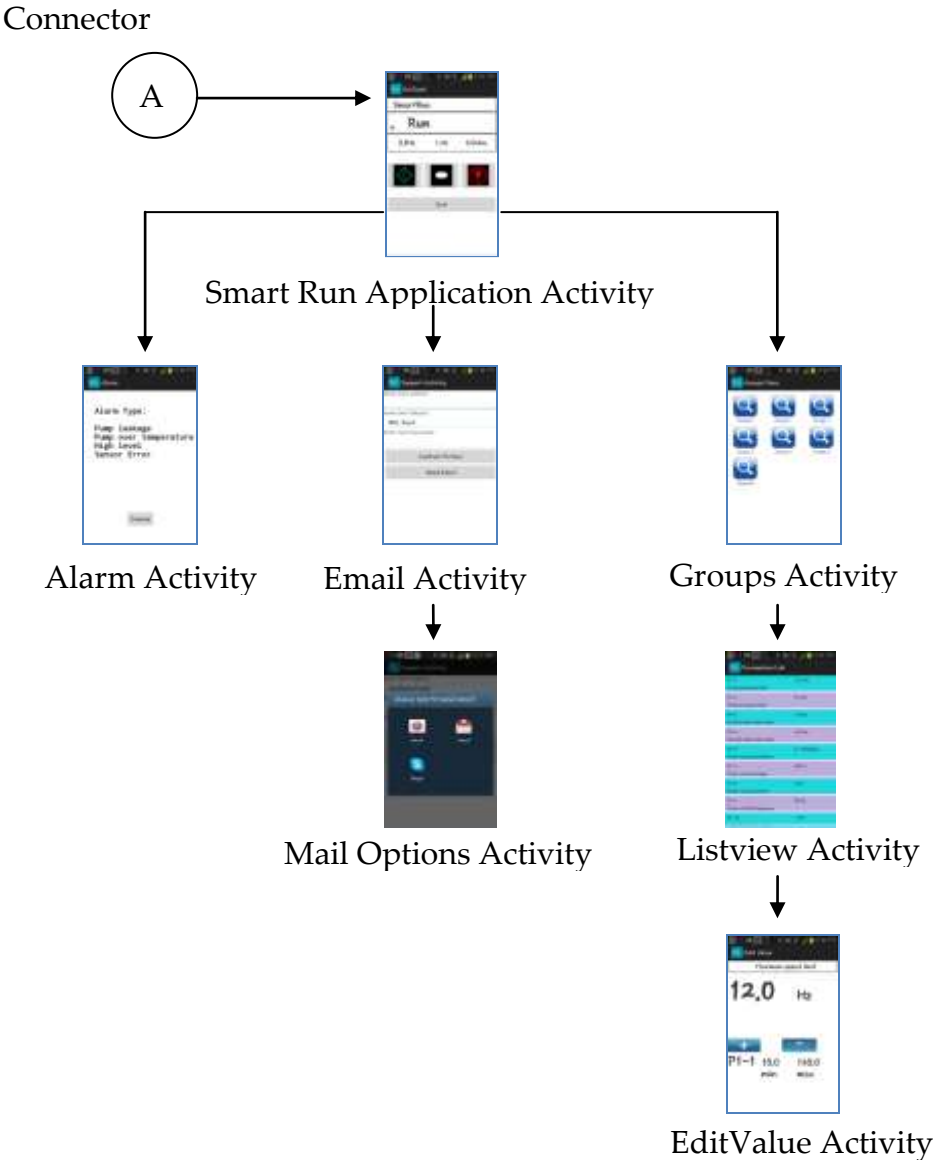
Appendix A: Application Flow




Connector
A
Smart Run Application Activity
Alarm Activity
Email Activity
Groups Activity
Mail Options Activity
Listview Activity
EditValue Activity

Appendix B: User manual

Overview : This section describes the prerequisites and the procedure for using the designed prototype Smart phone application to communicate with smart run or with dewatering pumps hardware.

Note : This application is a prototype design, developed to establish a working model for communicating with smart run. User interface and the layout design are only initial design models. Any bugs and application improvements are welcomed.

Prerequisites for communicating with smart run :

1. Smart Run with attached Optistick (Bluetooth Transceiver)
2. Android OS device (Smart Phone / Tablet PCs)
   a. Minimum Android Version : 3.1
   b. Maximum Android Version : 4.2
3. Bluetooth feature
   a. Classic Bluetooth
   b. Devices < Bluetooth 4.0
4. Xylem SRC mobile application installed

Note : Can be installed using the installation file, contact Xylem, RCE department.

Prerequisites for communicating with Dewatering pumps hardware :

1. Dewatering pumps equipped with hardware
2. Android OS device(Smart Phone / Tablet PCs)
   a. Minimum Android Version : 3.1
   b. Maximum Android Version : 4.3
3. Bluetooth feature
   a. Classic Bluetooth / Bluetooth 4.0
4. Xylem SRC mobile application installed

Note : Can be installed using the installation file, contact Xylem, RCE department.

Use case procedure with Smart Run :

Launch Application

1. Launch application using launch icon from the screen.
2. Login screen with user fields will be displayed.

Help about application

3. Select Help from device menu button press for information about application.

Change Language

4. Select Change Language from device menu button press to Choose language if required.
   a. Default language is set with English.
   b. Currently supports two languages includes English and Swedish.
   c. Select language from the dropdown list and press return button to apply.

Application Login

5. Enter the username and password provided by the administrator, Xylem RCE department.
   a. After entering username and password press login button.
   b. Entering wrong details shows up a warning message.
   c. Contact Xylem RCE department for right credentials.
   d. Successful login starts the next activity Select Activity.

Connection Choices

6. Select choices to connect with Smart Run and Dewatering Pumps will be shown.
   a. Smart Run Image button to connect with Smart Run.
   b. Dewatering Image button to connect with Dewatering pumps.

Connecting to Smart run

7. Select connection with smart run
   a. Pops up request to enable Bluetooth if turned off.

b. Scans local Bluetooth devices and shows list of available devices with device name and MAC address.
c. Select from list items displaying Optistick as device name and with respective MAC address.
d. Requests for pairing during first time connection, enter default pairing code "0000".
e. After successful pairing system starts transmitting initial display commands. Displays live smart run's status one among the following as :
    a. Stop along with voltage, power and phase ratings.
    b. Run along with current, voltage and power ratings.
    c. Standby mode.

Alarm Notifications

8. Alternatively displays alarm notification with warning tone and type of alarm in case of any alarm in smart run.
    a. In case of alarm, press dismiss button shown on the alarm notification screen.
    b. Alarm notification pops up continuously until the problem is fixed in smart run.
    c. Fixing the alarm issue in smart run stops the alarm notification.

User Buttons

9. Three user buttons are provided, namely :
    a. Start b. Stop c. Navigate

Start Smart run

10. Press start button to start the smart run.

Stop Smart run

11. Press stop button to stop the smart run.

View Parameters

12. Press navigate button to go to parameters groups.
13. Pressing navigate button displays new activity with group buttons according to the password level set on smart run.

Currently three password levels groups are categorized.

a. Basic level
b. Advanced level
c. Extended level

Contact admin to know how to unlock these levels in case of requirement.

14. Press device back button to go back to SRC panel activity.
15. Pressing any of the group button, system starts retrieving corresponding parameters and a list is displayed upon retrieving with parameter's id, description, value and its units. This process will take a while and depends on number of parameters to show in the group, meanwhile a wait dialog with loading animation is shown during this process.
16. Smart run's parameters and their value can been seen from the list view. Scroll down if the number of parameters exceeds the device' screen layout. Press device back button to go back to groups activity.

Change parameter value

17. Select an item from the list to change the parameter value, a new screen with selected parameter will be opened.
18. Two user button are provided to increase or decrease a value, they are :

a. Plus

b. Minus

19. Press plus button to increase a value.
    a. On this button press, system checks if value is within the limits of parameter which is defined internally.
    b. If the value is within the limits a value is incremented by one step.
    c. If the value reaches the maximum limit a warning message is displayed showing "**Reached Max**".
20. Press minus button to decrease a value.
    a. On this button press, system checks if the value is within the limits of parameter which is defined internally.
    b. If the value is within the limits a value is decremented by one step.
    c. If the value reaches the minimum limit a warning message is displayed showing "**Reached Min**".
21. Press device back button to go back List view screen, if no

value is changed from its original value from the list the system simply returns to the list view screen.

22. If a value is changed (increased or decreased) from its original value, press device' back button to apply the change in smart run.
23. Then the changed value is applied to smart run and also updates the value in application database.
24. Similarly follow the steps from 17 to 23 to change any of the lists parameter.

Support Service (Email parameters / Email a picture)

25. During SRC panel activity press device' menu button and select email parameters or email a picture from the dropdown menu list as per requirement.
26. Select Email parameters to send smart run's parameters to support department.
    a. This process will take a while as the system starts retrieving smart runs parameters.
    b. A dialog with loading parameters animation is displayed during this process.
    c. After downloading all the parameters the wait dialog is dismissed and a dialog with choice of mailing will be displayed.
    d. On selection of mailing client, the downloaded parameters value, mailing subject, mailing address is automatically copied to the mailing application.
    e. During this period it is possible to add a new email address and a default support address is copied by default.
    f. Follow usual procedure as sending email once after the data is copied to the mailing client.
    g. After successful mailing the system automatically returns to SRC panel activity.
27. Select Email a picture to send smart run wiring connections or scenario of problem to support department.
    a. Opens a new screen with user fields to enter fault description.
    b. Default mailing address is loaded and also possible to add a new mailing address if required.
    c. Press capture picture button to start camera and follow the on screen instructions to take a picture.

d. Press send mail button, a request to use built-in mailing options will be displayed.
e. Selecting mailing option starts the mailing application and automatically copies the data (picture, fault description, subject and mailing address) to the application and thereby follow usual procedure to send a mail.
f. After successful mailing the system automatically return to SRC panel activity.

Use case procedure with Dewatering pump hardware :

1. Follow steps 1 to 6 similar as above in use case procedure with smart run.

Connecting to Dewatering pumps hardware

2. Select connection with Dewatering
   a. Pops up request to enable Bluetooth if turned off.
   b. Scans local Bluetooth devices and shows list of available devices with device name and MAC address.
   c. Select from list items displaying hardware name with respective MAC address.
   d. Requests for pairing during first time connection, enter default pairing code “1234”.
   e. After successful pairing system starts dewatering application screen.

Enquire data

3. Press any of the buttons to retrieve corresponding information from the dewatering pumps.

Appendix C: Alarm Status

Alarm	Pump Leakage	Pump Over temp	High Level	Sensor Error	Alarm Active
0					
1	X				
2		X			
3	X	X			
4			X		
5	X		X		
6		X	X		
7	X	X	X		
8				X	
9	X			X	
10		X		X	
11	X	X		X	
12			X	X	
13	X		X	X	
14		X	X	X	
15	X	X	X	X	
16					X
17	X				X
18		X			X
19	X	X			X
20			X		X
21	X		X		X
22		X	X		X
23	X	X	X		X
24				X	X
25	X			X	X
26		X		X	X
27	X	X		X	X
28			X	X	X
29	X		X	X	X
30		X	X	X	X
31	X	X	X	X	X